

0057458

BHI-01544

Rev. 0

RECEIVED
JUN 25 2002

EDMC

Remedial Investigation Data Quality Objective Summary Report for the 200-PW-1 Operable Unit Dispersed Carbon Tetrachloride Vadose Zone Plume - Step I

***Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Environmental Restoration***

Submitted by: Bechtel Hanford, Inc.

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.
Available in paper copy and microfiche.

Available for a processing fee to U.S. Department of Energy
and its contractors from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
(865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov
online ordering: <http://www.doe.gov/bridge>

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(800) 553-6847
fax: (703) 605.6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/ordering.htm>

Printed in the United States of America

DISCLM-5.CHP (11/99)


APPROVAL PAGE

Title: Remedial Investigation Data Quality Objective Summary Report for the
200-PW-1 Operable Unit Dispersed Carbon Tetrachloride Vadose Zone
Plume – Step I


Approval: L. R. Curry, Groundwater/Vadose Zone Integration Project Engineer

 5/29/02
Signature Date

B. H. Ford, Groundwater/Vadose Zone Integration Project, 200 Area
Assessment Task Lead

 5/29/02
Signature Date

L. M. Dittmer, Groundwater/Vadose Zone Integration Project
Environmental Lead

 5/21/2002
Signature Date

*The approval signatures on this page indicate that this document has been
authorized for information release to the public through appropriate channels. No
other forms or signatures are required to document this information release.*

BHI-DIS MR 5/30/02

Remedial Investigation Data Quality Objective Summary Report for the 200-PW-1 Operable Unit Dispersed Carbon Tetrachloride Vadose Zone Plume – Step I

Author

R. G. Bauer
CH2M Hill Hanford

Date Published

May 2002

TABLE OF CONTENTS

1.0	STEP 1 – STATE THE PROBLEM	1-1
1.1	INTRODUCTION.....	1-1
1.2	PROJECT SCOPE.....	1-1
1.2.1	Carbon Tetrachloride Remediation Strategy	1-5
1.3	PROJECT OBJECTIVES	1-6
1.4	PROJECT ASSUMPTIONS	1-8
1.5	PROJECT ISSUES.....	1-10
1.5.1	Global Issues	1-10
1.5.2	Project Technical Issues	1-10
1.6	CARBON TETRACHLORIDE SOURCE TERM AND REMEDIATION BACKGROUND INFORMATION.....	1-10
1.6.1	Carbon Tetrachloride Drum Storage Releases	1-11
1.6.2	Z Plant Complex Heating, Ventilation, and Air Conditioning Releases	1-11
1.6.3	Z Plant Complex Process Releases	1-13
1.6.4	Z Plant Complex Piping and Drain Leaks.....	1-13
1.6.5	Discharge Pipeline Leakage	1-13
1.6.6	Deliberate Discharges.....	1-13
1.6.7	Burial Ground Disposal of Carbon Tetrachloride-Containing Wastes ..	1-14
1.7	CONTAMINANTS OF CONCERN.....	1-20
1.8	POTENTIAL ARARS AND PRGS	1-21
1.9	GENERAL EXPOSURE SCENARIOS	1-22
1.10	MILESTONE DATES	1-22
1.11	PROJECT SCHEDULE	1-23
1.12	PRELIMINARY CONCEPTUAL CONTAMINANT DISTRIBUTION MODEL.....	1-23
1.13	CONCISE STATEMENT OF THE PROBLEM	1-26

Table of Contents

2.0	STEP 2 – IDENTIFY THE DECISION	2-1
3.0	STEP 3 – IDENTIFY THE INPUTS TO THE DECISION	3-1
3.1	BASIS FOR SETTING THE PRELIMINARY ACTION LEVEL	3-1
3.2	INFORMATION REQUIRED TO RESOLVE DECISION STATEMENTS	3-1
3.2.1	Data Gap Analysis	3-6
3.3	COMPUTATIONAL AND SURVEY/ANALYTICAL METHODS	3-6
3.3.1	Existing Models	3-6
3.3.2	Applicability of Available Models to the Dispersed Vadose Zone Carbon Tetrachloride Plume	3-7
3.4	ANALYTICAL PERFORMANCE REQUIREMENTS	3-10
4.0	STEP 4 – DEFINE THE BOUNDARIES OF THE STUDY	4-1
4.1	OBJECTIVE	4-1
4.2	DEFINE THE BOUNDARIES OF THE STUDY	4-1
4.3	SCALE OF DECISION MAKING	4-3
4.4	PRACTICAL CONSTRAINTS	4-3
5.0	STEP 5 – DEVELOP A DECISION RULE	5-1
5.1	INPUTS NEEDED TO DEVELOP DECISION RULES	5-1
5.2	DECISION RULES	5-2
6.0	STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS	6-1
6.1	UNCERTAINTY DISCUSSION	6-1
7.0	STEP 7 – OPTIMIZE THE DESIGN	7-1
7.1	PURPOSE	7-1
7.2	OPTIMIZE THE DESIGN	7-1
7.3	SAMPLING OBJECTIVES	7-3

Table of Contents

7.4	NON-STATISTICAL IMPLEMENTATION DESIGN	7-3
7.4.1	Step I Characterization	7-4
7.4.2	Potential Sample Design Limitations	7-17
8.0	OBSERVATIONS AND RECOMMENDATIONS	8-1
8.1	REMEDIAL ACTION CONSIDERATIONS	8-1
8.2	PERIODIC REVIEW OF DATA QUALITY OBJECTIVES	8-1
9.0	REFERENCES	9-1

FIGURES

1-1.	Location of the Hanford Site and 200-PW-1 Operable Unit Waste Sites	1-2
1-2.	Study Area for the Dispersed Carbon Tetrachloride Plume Investigation	1-3
1-3.	Locations of Known Carbon Tetrachloride Plumes in the Groundwater and Upper Vadose Zone in the 200 West Area	1-4
1-4.	Relationships Between DQOs that Support Development of a Carbon Tetrachloride Remediation Design	1-7
1-5.	Potential Carbon Tetrachloride Release Modes in the 200 West Area	1-12
1-6.	Preliminary Conceptual Contaminant Distribution Model	1-27
1-7.	Sanitary, Raw Water, and Process Discharge Pipelines Located Near the Z Plant Complex Release Areas	1-28
7-1.	Characterization Stage, Decision Unit, and Relative Uncertainty Relationships	7-5
7-2.	Shallow Soil Vapor Sampling Around the Plutonium Finishing Plant	7-11
7-3.	Typical Storage Module in Low-Level Burial Ground Retrievable Storage Units Showing Vent Riser	7-12
7-4.	Location of Drum Storage Area and French Drains Within the PFP Protected Area ..	7-13
7-5.	Location of Liquid Waste Discharge Sites	7-14
7-6.	Location of Liquid Discharge Pipelines	7-15

TABLES

1-1.	DQO Scoping Team Members.....	1-15
1-2.	DQO Workshop Team Members	1-15
1-3.	DQO Integration Team Members.....	1-16
1-4.	DQO Key Decision Makers.	1-16
1-5.	Existing Documents and Data Sources for 200-PW-1 Operable Unit	1-17
1-6.	List of Potential ARARs and PRGs.	1-22
1-7.	General Exposure Scenarios.....	1-22
1-8.	Regulatory Milestones.....	1-22
1-9.	Project Schedule.....	1-23
1-10.	Preliminary Conceptual Contaminant Distribution Model Discussion.....	1-23
1-11.	Concise Statement of the Problem.	1-26
2-1.	Summary of DQO Step 2 Information	2-1
3-1.	Basis for Setting Preliminary Action Level.	3-1
3-2.	Required Information and References.....	3-2
3-3.	Information Required to Resolve the Decision Statements.....	3-6
3-4.	Details on Identified Computational Methods.	3-7
3-5.	Potentially Appropriate Survey and/or Analytical Methods	3-8
3-6.	Analytical Performance Requirements.....	3-11
4-1.	Characteristics that Define the Population of Interest.....	4-1
4-2.	Geographic Boundaries of the Investigation.....	4-1
4-3.	Strata with Homogeneous Characteristics.....	4-2
4-4.	Temporal Boundaries of the Investigation.	4-2
4-5.	Scale of Decision Making.	4-3
4-6.	Practical Constraints on Data Collection.....	4-4
5-1.	Decision Statements.	5-1
5-2.	Inputs Needed to Develop Decision Rules.....	5-2
5-3.	Decision Rules.....	5-2
6-1.	Relative Uncertainty Ranking for Study Decisions.	6-2
7-1.	Determine Data Collection Design.....	7-1
7-2.	Determine Non-Statistical Sampling Design.	7-1
7-3.	Potential Field Screening Alternatives.....	7-2
7-4.	Characterization Goals and Drivers.	7-3
7-5.	Sampling Design to Investigate Potential Carbon Tetrachloride Release Modes.....	7-6
7-6.	Step I Sampling Design.....	7-7
7-7.	Site Size and Number of Direct-Push Technology Locations in Liquid Waste Discharge Sites.....	7-16

ACRONYMS

AA	alternative action
AEA	alpha energy analysts
ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
bgs	below ground surface
BHI	Bechtel Hanford, Inc.
CAS	Chemical Abstract Services
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CHI	CH2M HILL Hanford, Inc.
COC	contaminant of concern
COPC	contaminant of potential concern
DBP	dibutyl phosphate
DBBP	dibutyl butyl phosphonate
DNAPL	dense, non-aqueous phase liquid
DOE	U.S. Department of Energy
DQO	data quality objective
DR	decision rule
DS	decision statement
EPA	U.S. Environmental Protection Agency
ERC	Environmental Restoration Contractor
FS	feasibility study
FY	fiscal year
GCMS	gas chromatograph/mass spectrometry
GW	groundwater
HEIS	Hanford Environmental Information System
HVAC	heating, ventilation, and air conditioning
IC	ion chromatography
ITRD	Innovative Treatment Remediation Demonstration
K _d	distribution coefficient
LLWMA	low-level waste management area
MBP	monobutyl phosphate
MCL	maximum contaminant level
MTCA	<i>Model Toxics Control Act</i>
OU	operable unit
OVM	organic vapor monitor
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
PQL	practical quantitation limit

PRF	Plutonium Reclamation Facility
PRG	preliminary remediation goal
PSQ	principal study question
PUREX	Plutonium Uranium Reduction Extraction (Facility)
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RECUPLEX	Recovery of Uranium and Plutonium by Extraction
REDOX	Reduction-Oxidation (Facility)
RG	rubber glove
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
RMA	remote mechanical operations "A" line
RMC	remote mechanical operations "C" line
ROD	Record of Decision
SAP	sampling and analysis plan
STOMP	Subsurface Transport Over Multiple Phases
SVE	soil vapor extraction
TIC	tentatively identified compound
TBP	tributyl phosphate
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>
TRU	waste materials contaminated with 100 nCi/g of transuranic materials having half-lives longer than 20 years
UCL	upper confidence level
VOA	volatile organic analyte
WAC	<i>Washington Administrative Code</i>
WIDS	Waste Information Data System

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
<i>If You Know</i>	<i>Multiply By</i>	<i>To Get</i>	<i>If You Know</i>	<i>Multiply By</i>	<i>To Get</i>
Length			Length		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			Area		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.0836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			Mass (weight)		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			Volume		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			Radioactivity		
picocuries	37	millibecquerel	millibecquerel	0.027	picocuries

1.0 STEP 1 – STATE THE PROBLEM

The purpose of data quality objective (DQO) Step 1 is to state the problem clearly and concisely and to ensure that the focus of the study is unambiguous.

1.1 INTRODUCTION

This DQO summary report has been developed to support the remedial investigation/feasibility study (RI/FS) and remedial action decision-making processes for the dispersed carbon tetrachloride plume in the vadose zone. This plume is associated principally with the waste sites in the 200-PW-1 Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit (OU). This summary report follows and is distinct from the DQO summary report for the 200-PW-1 OU representative waste sites (Bauer 2002), which focused only on the contaminants resident within the contiguous boundaries of the 216-Z-1A Tile Field and the 216-Z-9 Trench.

The carbon tetrachloride vapor plume in the vadose zone under the 200 West Area was identified as a global issue that was not resolved in the 200-PW-1 OU representative waste site DQO summary report (Bauer 2002). The U.S. Environmental Protection Agency (EPA) subsequently determined that the scope of the 200-PW-1 RI/FS work plan should be expanded beyond the representative waste sites to include characterization of the vadose zone carbon tetrachloride plume. EPA's decision was the driver for this DQO project. EPA further suggested that the initial study area should be bounded by 20th Street, Camden Avenue, 16th Avenue, and Dayton Avenue in the 200 West Area and determined that investigation of the plume outside of this area would be the subject of later investigations.

The waste sites in the 200-PW-1 OU received effluents from the Z Plant complex, including the Plutonium Finishing Plant (PFP) processes, of which, carbon tetrachloride was a significant component. The aqueous and organic discharges to the vadose zone through the 200-PW-1 OU waste sites resulted in carbon tetrachloride contamination of the vadose zone and groundwater in the 200 West Area. A map of the Hanford Site is provided in Figure 1-1 and depicts the 200 Areas and vicinity (i.e., the location of the 200-PW-1 OU). Figure 1-2 shows the geographical focus area for this DQO investigation. Figure 1-3 presents a groundwater map indicating the carbon tetrachloride plume concentrations.

1.2 PROJECT SCOPE

This DQO summary report focuses on the carbon tetrachloride contamination in the vadose zone as it impacts groundwater under the Hanford Site's 200 West Area. The scope of this project includes the DQO process and the development of a sampling and analysis plan (SAP). This DQO summary report and the associated SAP are the initial RI characterization steps within the overall dispersed carbon tetrachloride vadose zone plume remediation strategy that will be detailed in the work plan and briefly summarized in Section 1.2.1.

Figure 1-1. Location of the Hanford Site and 200-PW-1 Operable Unit Waste Sites.

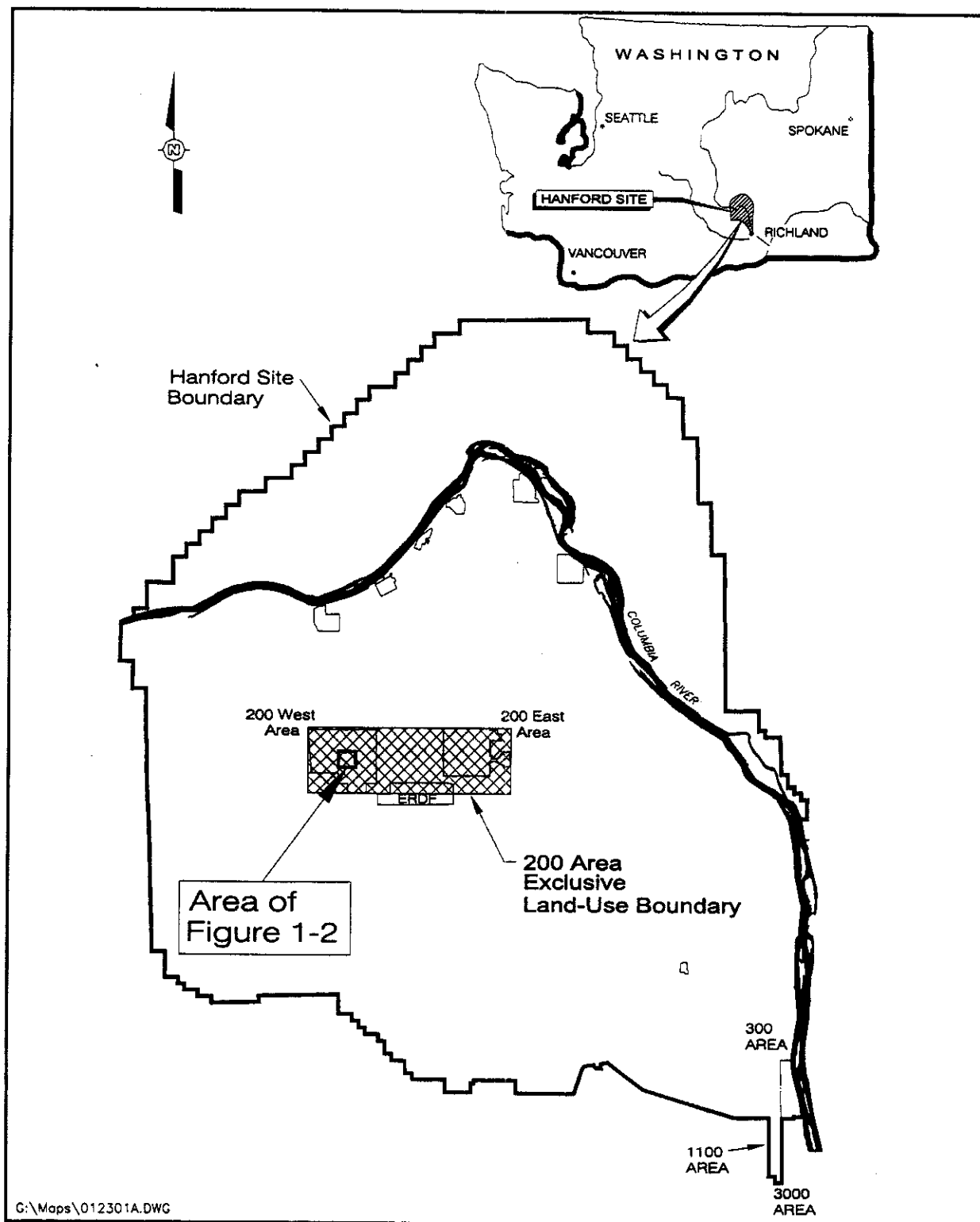


Figure 1-2. Study Area for the Dispersed Carbon Tetrachloride Plume Investigation.

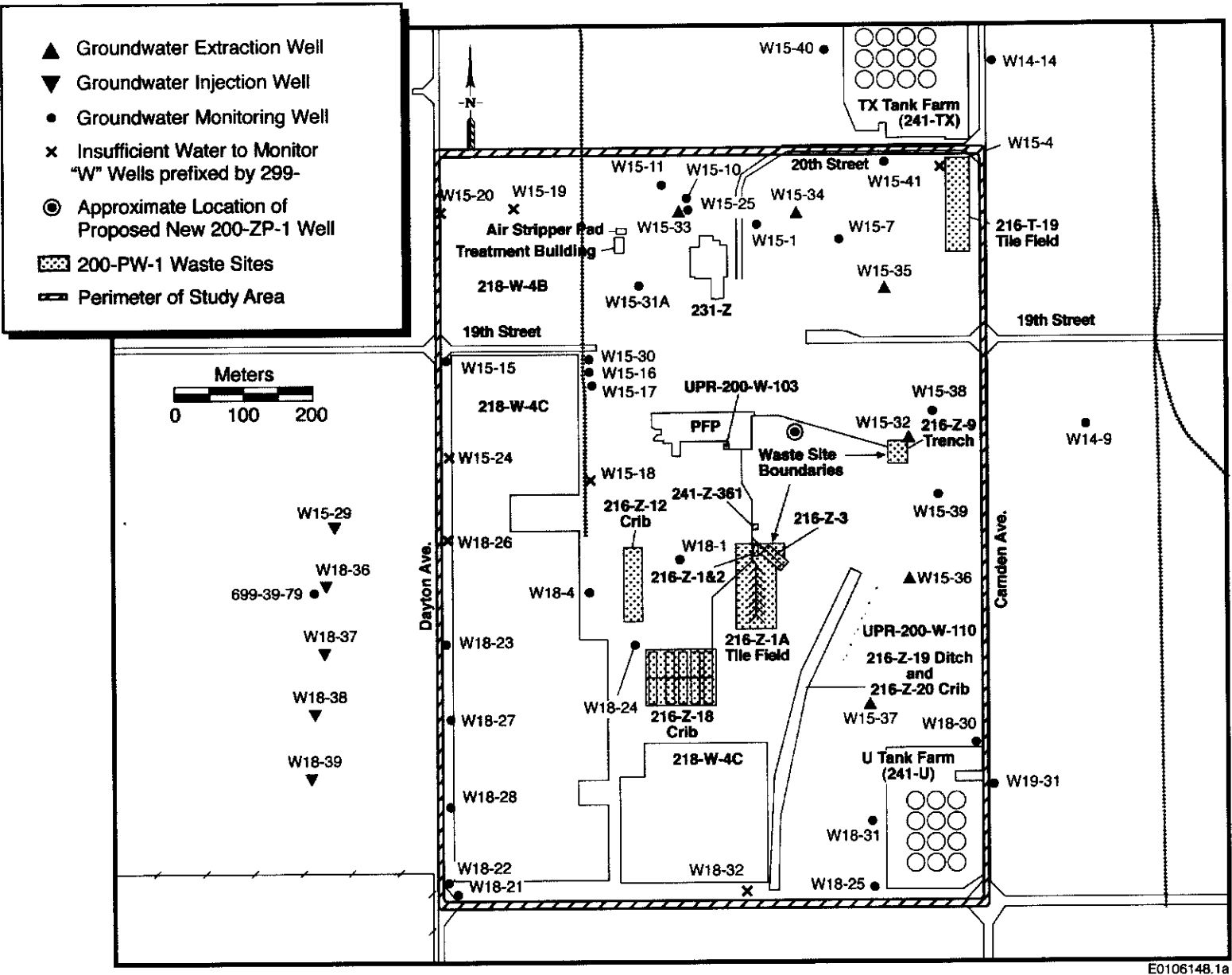
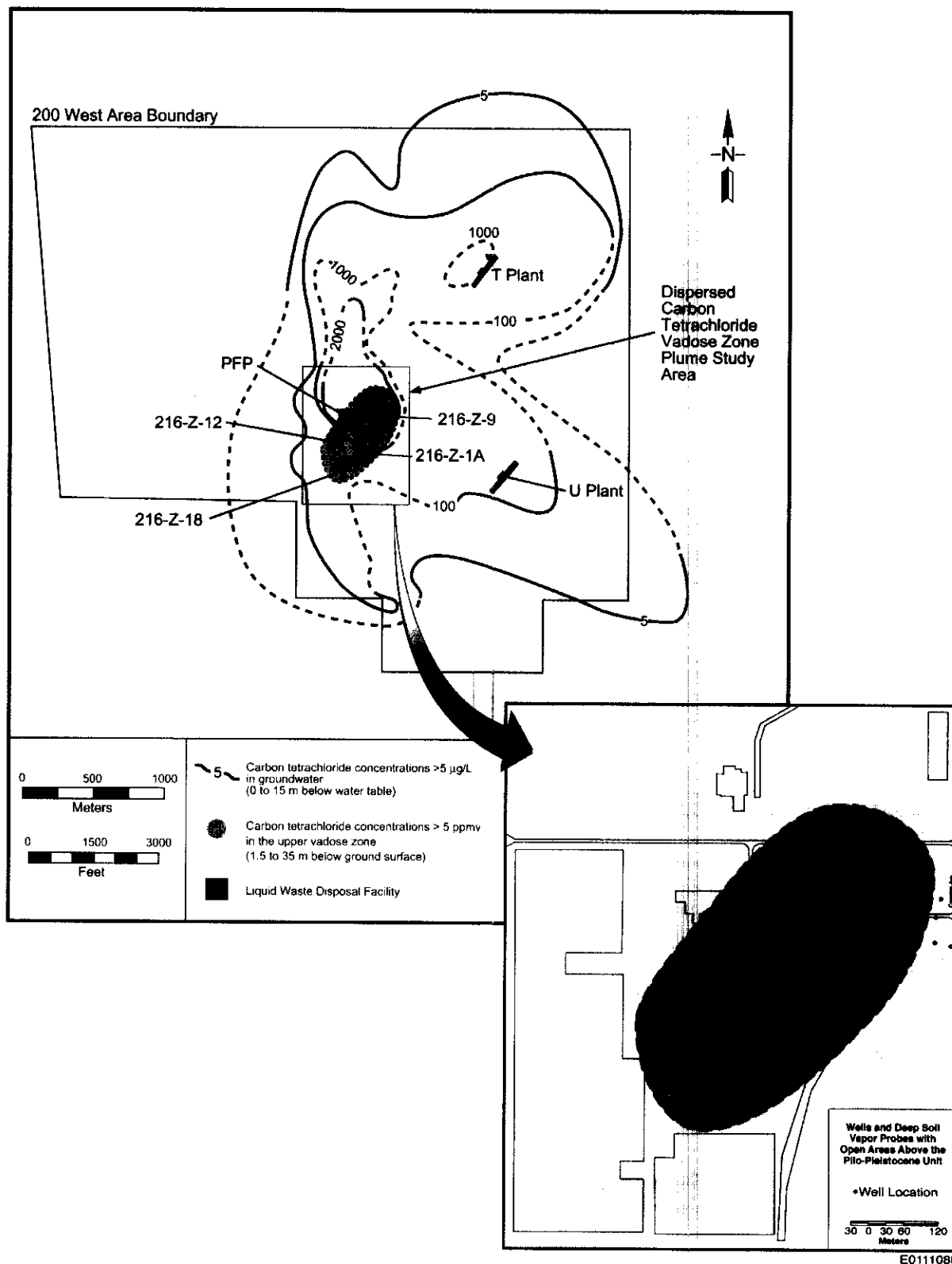


Figure 1-3. Locations of Known Carbon Tetrachloride Plumes in the Groundwater and Upper Vadose Zone in the 200 West Area.



Step 1 – State the Problem

The *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program* (hereinafter referred to as the Implementation Plan) (DOE-RL 1999) presents a consistent approach for data collection activities associated with 200 Area assessment and remediation activities. The activities include all phases of sampling required to support the completion of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) process outlined in Section 2.3 and depicted in Figure 2-2 of the Implementation Plan (DOE-RL 1999). The primary activity for the dispersed carbon tetrachloride vadose zone plume includes the following:

- Develop a carbon tetrachloride sampling and analytical strategy for the vadose zone. The sampling strategy will focus on verifying the conceptual contaminant distribution model(s) and will support remedial action decision making through risk evaluations and FSs.

This DQO process supports data collection that will enable the evaluation of remedial alternatives and the selection of a preferred alternative through the RI/FS process. Additional DQO processes will be necessary to define sampling requirements for later phases of data collection.

1.2.1 Carbon Tetrachloride Remediation Strategy

The carbon tetrachloride plume remediation strategy integrates the interim actions and associated characterization needs with the CERCLA RI/FS requirements to develop a process for reaching final decisions for the remediation of carbon tetrachloride in the 200 West Area. The overall objective of that strategy is to define the tasks and an implementation schedule to support final remediation decisions. The carbon tetrachloride plume remediation strategy is intended to integrate activities and requirements associated with the following:

- The action memorandum for vadose zone soil vapor extraction (SVE) under the 200-PW-1 source (formerly 200-ZP-2) OU (EPA and Ecology 1992)
- The CERCLA RI/FS process for the 200-PW-1 OU, which contains the waste sites that received carbon tetrachloride waste
- The interim action Record of Decision (ROD) for groundwater pump and treat under the 200-ZP-1 Groundwater OU (EPA et al. 1995)
- The CERCLA RI/FS process for the 200 Area groundwater, which contains the carbon tetrachloride groundwater plume
- Action items identified from the calendar year 2000 EPA 5-year review (EPA 2001)

- Science and technology programs that address carbon tetrachloride needs and the recommendations developed under the Innovative Treatment Remediation Demonstration (ITRD) Program.
- The Groundwater/Vadose Zone Integration Project's System Assessment Capability modeling efforts that are underway to support carbon tetrachloride fate and transport models.

The remediation strategy is initially focused on completion of the 200-PW-1 RI/FS process and continued operation of the interim actions. The carbon tetrachloride plume remediation strategy also recognizes opportunities to enhance the effectiveness of SVE and/or groundwater pump-and-treat interim actions based on knowledge gained from the 200-PW-1 RI (e.g., locations or concentrations of contaminants in the vadose zone) and/or advances in technology. Results of the 200-PW-1 source investigation will help focus subsequent field activities to investigate the carbon tetrachloride groundwater plume and the presence of dense, nonaqueous phase liquid (DNAPL) in the aquifer.

The dispersed carbon tetrachloride vadose zone plume will be investigated in two steps. Step I will investigate the shallow to intermediate-depth vadose zone to identify potential unknown releases of carbon tetrachloride, and Step II will investigate the intermediate-to-deep vadose zone to the top of the water table. The intermediate-depth zone corresponds to the vicinity of the Plio-Pleistocene unit. The DQO effort for the known representative source-term waste site investigations has been completed (Bauer 2002). The associated SAP is included in the work plan (Appendix A of DOE-RL 2002).

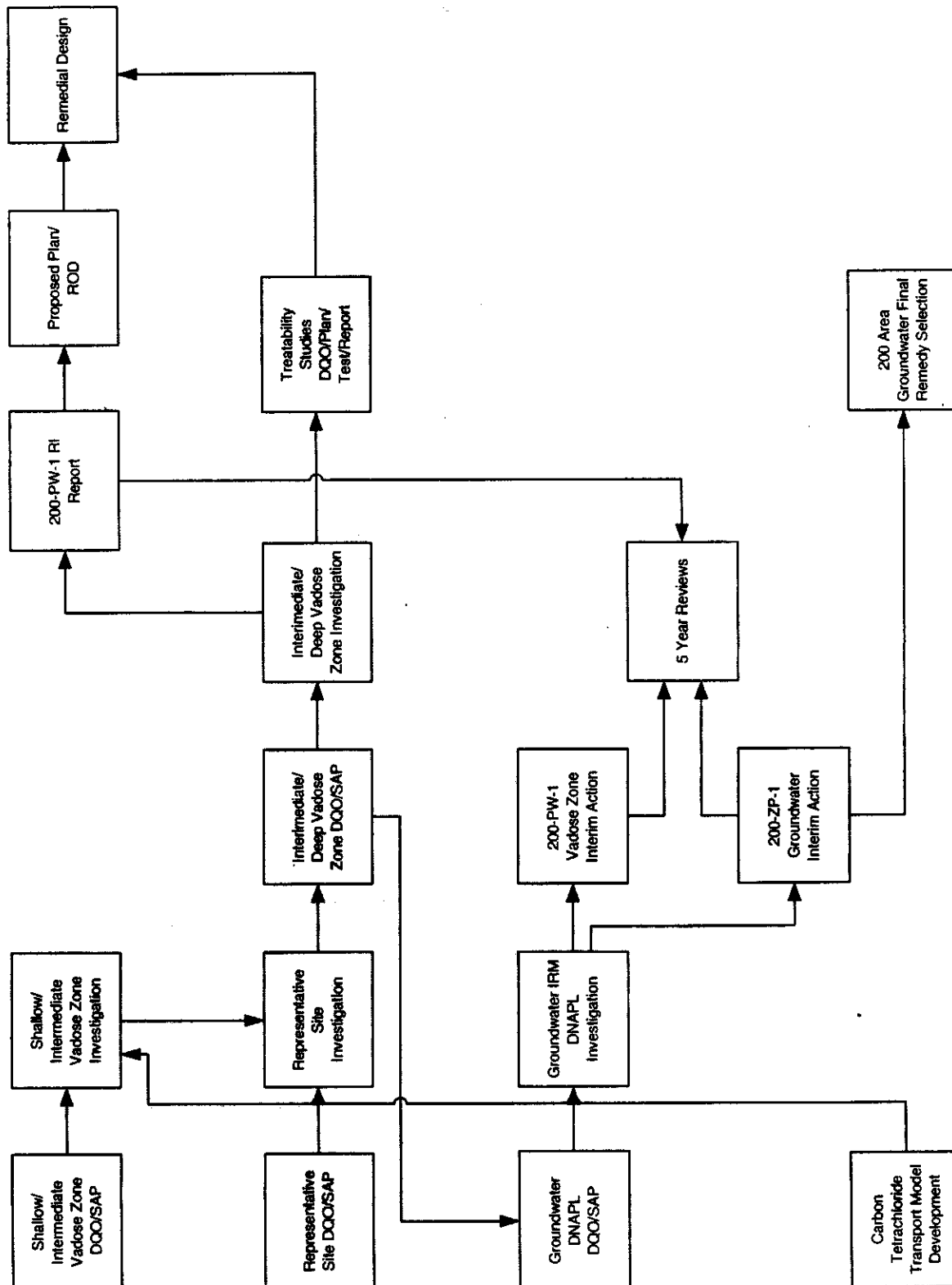
Based on the results of the Step I carbon tetrachloride investigation, a Step II DQO and SAP will be developed for intermediate and deep vadose zone investigation. Step II will likely require the use of boreholes for sampling in the deep vadose zone. A flowchart of the relationships between this and subsequent DQOs that support the development of a carbon tetrachloride remediation design is presented in Figure 1-4.

1.3 PROJECT OBJECTIVES

The objectives of this DQO process include the following:

- Develop the sampling and analytical activities and the requirements to locate and characterize active vadose zone sources of carbon tetrachloride contamination to groundwater in the 200 West Area to support selection of remedial actions or identification of alternative groundwater contamination limits.

Figure 1-4. Relationships Between DQOs that Support Development of a Carbon Tetrachloride Remediation Design.



Step 1 – State the Problem

- Develop conceptual contaminant distribution model(s) that depict the current distribution of carbon tetrachloride within the vadose zone in 200 West Area. This includes the potential for lateral migration of aqueous and/or DNAPLs beyond known waste site boundaries.
- Develop an understanding of the mechanisms that lead to carbon tetrachloride contamination of groundwater.

Sampling and analytical activities are necessary to support the RI/FS process and remedial decision making. Additionally, the DQO process supports development of a SAP for the RI, which will be included as an appendix to the RI/FS work plan.

Possible alternatives identified in the Implementation Plan (DOE-RL 1999) include the following:

- No Action alternative (no institutional controls)
- Engineered multimedia barrier
- In situ vapor extraction
- Monitored natural attenuation (with institutional controls).

Additional alternatives may also be considered (e.g., bio-remediation).

1.4 PROJECT ASSUMPTIONS

Project assumptions for the RI include the following:

- The DQO process will follow BHI-EE-01, *Environmental Investigations Procedures*, Procedure 1.2, "Data Quality Objectives," and Section 6.1 of the Implementation Plan (DOE-RL 1999).
- The RI will be designed to obtain sufficient information to plan remedial actions; however, the extent and application of land use in the 200 West Area has not been approved by the regulators to date. Consistent with other 200 Area RI/FS DQOs, industrial land use is assumed within the 200 Area exclusive-use boundary, and conservation (mining) is assumed for areas outside of the 200 Area exclusive-use boundary in accordance with the *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1999a) and the ROD (DOE 1999b).
- Existing characterization data from vadose zone and groundwater monitoring wells have been used to develop the preliminary conceptual contaminant distribution model for this DQO process. Known and suspect carbon tetrachloride release sites investigated for this DQO process have not been limited to the 200-PW-1 OU waste sites.

Step 1 – State the Problem

- Potential data uses that need to be considered when developing the DQOs include refining the preliminary conceptual contaminant distribution model(s), evaluating the risk assessment remedial action alternatives and remedial action decisions, and ensuring worker health and safety. However, this DQO effort is focused on the RI/FS process and, therefore, will not include decision making for ecological impacts from exposure to carbon tetrachloride vapors. (These topics will be the subject of a subsequent DQO effort.)
- The RI (i.e., initial OU characterization) will validate, or provide the basis to refine, the conceptual contaminant distribution model through characterization of the vadose zone. The conceptual contaminant distribution model and risk assessment results will be used to develop and evaluate remedial action alternatives in a FS/proposed plan.
- The Implementation Plan (DOE-RL 1999) outlines the assessment and remediation approach to be followed for the OU:
 - Defines the regulatory framework
 - Provides background information on 200 Area site conditions, operational history, and secondary plans (e.g., quality assurance, health and safety, information management, and waste management)
 - Provides governing assumptions, including preliminary applicable or relevant and appropriate requirements (ARARs), land-use considerations, remedial action objectives, and alternatives.
- A subsequent DQO process was conducted for designation of wastes that are generated during RI/FS characterization sampling.
- Supplemental sampling requirements that result from integration efforts with other projects are not addressed by this DQO effort.
- Two wells (299-W15-84 and 299-W15-95) have been extended approximately 30.5 m (100 ft) through the Plio-Pleistocene unit, near the 216-Z-9 Trench (BHI 2001). Split-spoon soil samples were analyzed for volatile organic analytes (VOAs), metals, gross alpha and beta, plutonium (and several other radionuclides), and oil and grease. Soil vapor samples were analyzed for VOAs. A new well (299-W15-42) was drilled 87.3 m (286.6 ft) below ground surface (bgs) and completed as a groundwater well near the PFP (Faurote 2002). Soil samples were analyzed for a similar list of constituents as were analyzed at 216-Z-9, and soil vapor samples were analyzed for VOAs. In addition, RI/FS characterization is planned for the 216-T-26 Crib site. Some of the data accumulated through these activities will augment the information needs of this DQO process.
- Using Henry's law, the carbon tetrachloride vapor concentration that would contaminate groundwater to the maximum contaminant level of 5 parts per billion (ppb) has been calculated as 1 part per million by volume (ppmv). Soil vapor that is saturated with carbon

Step 1 – State the Problem

tetrachloride (i.e., the maximum vapor concentration) has a carbon tetrachloride concentration of 120,000 ppmv.

- The total carbon tetrachloride concentration in soil that signifies the presence of DNAPL depends in part on the moisture content, fraction of organic carbon, and porosity of the soil. For a soil sample with 20% moisture, 0.0001 fraction of organic carbon, and 30% porosity, a carbon tetrachloride concentration exceeding 180 mg/kg would signify the presence of DNAPL.
- Groundwater monitoring has been conducted extensively in the 200 West Area and groundwater carbon tetrachloride plume maps have been developed. However, vapor monitoring to date has only been performed in the vicinity of the 216-Z-1A Tile Field, 216-Z-9 Trench, 216-Z-12 Crib, and 216-Z-18 Crib.
- Two terms are defined for the purpose of this DQO process and the subsequent work plan and SAP. “Known and suspect release sites” are those locations where carbon tetrachloride is known or suspected to have been released to the vadose zone. The term “source” indicates aqueous, DNAPL, or vapor forms of carbon tetrachloride that contribute contaminant mass to groundwater.

1.5 PROJECT ISSUES

Project issues include the global issues that transcend the specific DQO project and the technical issues that are unique to the project. Both global and project technical issues have the potential to impact the sampling design or the DQOs for the project.

1.5.1 Global Issues

No global issues have been identified for this project.

1.5.2 Project Technical Issues

No project technical issues have been identified.

1.6 CARBON TETRACHLORIDE SOURCE TERM AND REMEDIATION BACKGROUND INFORMATION

This study identified seven potential modes by which carbon tetrachloride could be released to the environment:

- Carbon tetrachloride drum leakage to the ground in drum storage areas

Step 1 – State the Problem

- Heating, ventilation, and air conditioning (HVAC) system condensate releases to engineered waste sites
- Plant process leakage to the ground
- Z Plant complex piping and drain leaks
- Discharge pipeline leaks
- Deliberate discharges through engineered liquid waste sites
- Releases from materials in the burial grounds.

These release modes are depicted in Figure 1-5.

1.6.1 Carbon Tetrachloride Drum Storage Releases

Carbon tetrachloride was contained in drums and delivered to the 234-5Z Building by truck. The drums were stored on the loading dock and at grade level south of the chemical storage facility until transported to the Plutonium Reclamation Facility (PRF). At the PRF, the drums were carried on an elevator to the chemical makeup room on the fourth floor. One drum of carbon tetrachloride was reportedly spilled during handling. It is not known if any drums of carbon tetrachloride leaked while in storage outside the building. The empty drums were recycled and reused. Other chemicals may also have been stored in this location.

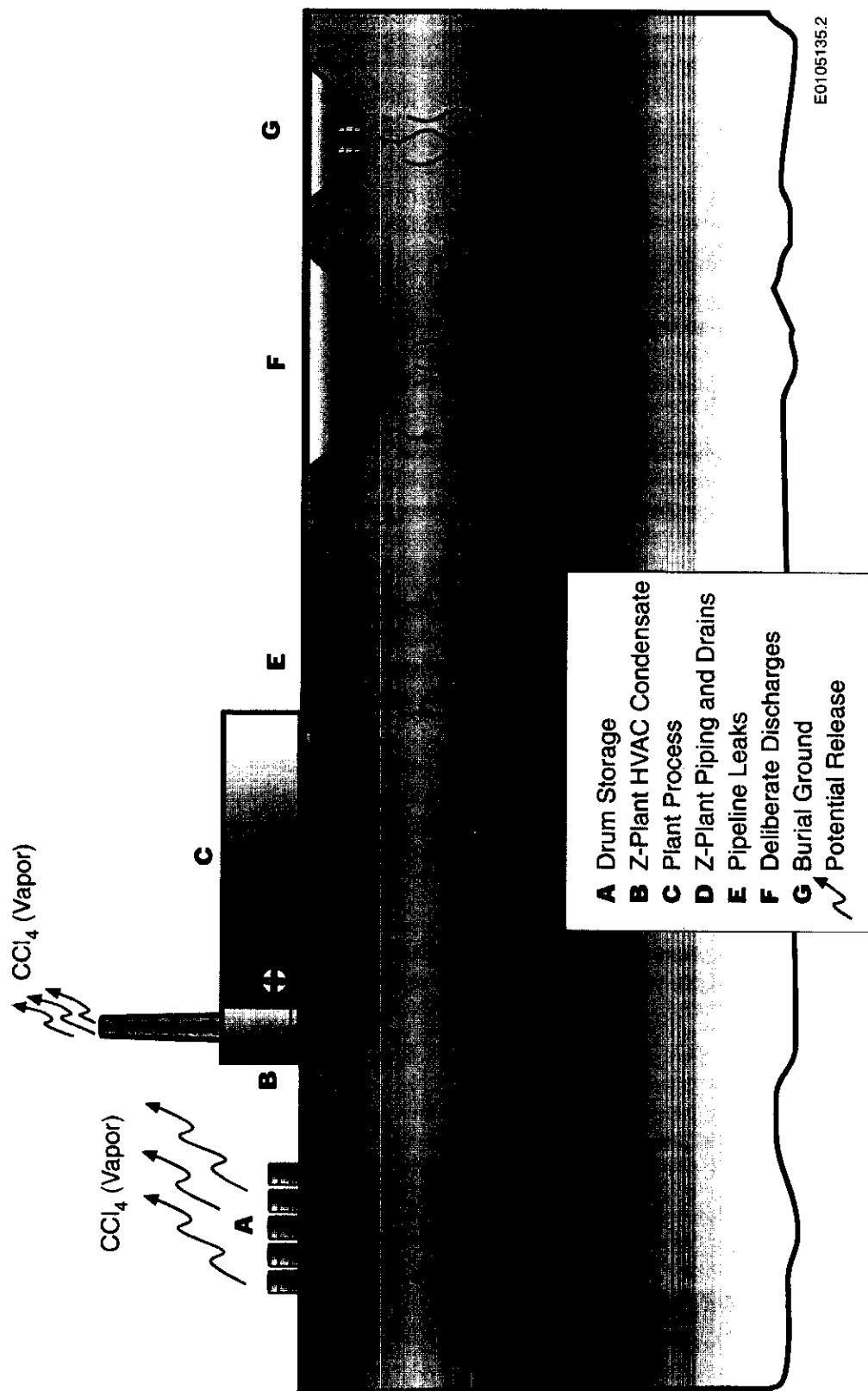
When PRF operations ended in December 1987, all carbon tetrachloride was removed from the facility and disposed in accordance with regulations. The carbon tetrachloride was placed in polyethylene bottles, surrounded by absorbent, and then overpacked in hazardous waste drums for shipment to the central hazardous waste storage facility. Carbon tetrachloride removal was completed in January 1988 (Jensen 1990).

In approximately 1989, a carbon tetrachloride storage tank was added to the chemical storage facility to store carbon tetrachloride for use in a new campaign. Several hundred gallons of carbon tetrachloride leaked from the tank to a secondary containment basin. The tank was subsequently drained and removed from service. The recovered carbon tetrachloride was pumped into drums and shipped out of the PFP complex.

1.6.2 Z Plant Complex Heating, Ventilation, and Air Conditioning Releases

Large amounts of carbon tetrachloride vaporized through the building's HVAC systems and were routed to stacks (e.g., 291-Z-1 Building stack system). Condensate containing small amounts of carbon tetrachloride was collected from these stacks and routed to engineered liquid discharge sites that included 216-Z-13, 216-Z-14, 216-Z-15, 216-Z-19, 216-Z-20, and 216-Z-21. It has been estimated that approximately 37% of the total carbon tetrachloride inventory delivered to Z Plant was lost to evaporation (Appendix A of DOE-RL 1991).

Figure 1-5. Potential Carbon Tetrachloride Release Modes in the 200 West Area.



Step 1 – State the Problem

1.6.3 Z Plant Complex Process Releases

Carbon tetrachloride releases from plant processes may have occurred during several disruptions within the Z Plant complex, and plutonium, americium, and/or uranium could have also been released. Based on Z Plant complex occurrence reports and process records, the released materials were normally recovered in waste tanks. The recovered materials were sampled and routed for rework in product recovery, were sent for waste treatment, or were routed to a waste disposal site.

All Z Plant complex operations were performed in hoods, in gloveboxes, or within rooms that were lined with stainless steel. Therefore, it is not likely that plant process releases could have discharged significant inventories of carbon tetrachloride directly to the underlying soils.

1.6.4 Z Plant Complex Piping and Drain Leaks

Several drawings (i.e., H-2-32528, H-2-15436, and H-2-97312) indicate the presence of pipelines under the Z Plant complex facilities. The condition of these waste transfer, stormwater, raw water, sanitary sewer, chemical routing, and process sewer lines is unknown so the leakage potential cannot be assessed at this time.

1.6.5 Discharge Pipeline Leakage

Carbon tetrachloride was possibly released from leaking discharge pipelines. These pipelines originated within the Z Plant complex and emptied into the known carbon tetrachloride waste sites (216-Z-9 Trench, 216-Z-1A Tile Field, 216-Z-18 Crib, and 216-Z-12 Crib). A remote camera survey was completed in 1993 of portions of the 216-Z-9 Trench waste discharge pipelines (840 and 840D). The video survey did not indicate breaks or major cracks; however, both lines exhibited areas of severe pitting and corrosion. It could not be determined if the pitting broke through the pipe walls or if small holes within the pipelines could have created leakage paths. These releases would account for a very small volume discharged to the vadose zone compared to the discharge of waste effluents (WHC 1994).

1.6.6 Deliberate Discharges

The primary known releases of carbon tetrachloride contamination in the 200 West Area are the subsurface infiltration facilities, which were used for soil column disposal of aqueous and organic liquid wastes associated with plutonium recovery operations within the PFP complex. Between 1955 and 1973, up to 580,000 L (153,120 gal) of liquid carbon tetrachloride mixed with other organic and aqueous actinide-bearing liquids are estimated to have been discharged to the soil column at three subsurface disposal facilities near the PFP: 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib. The 216-Z-12 Crib is estimated to have received a small volume of organics, which included carbon tetrachloride (Kasper 1982).

The organic solutions consisted of 50% to 85% (by volume) carbon tetrachloride mixed with tributyl phosphate (TBP), dibutyl butyl phosphonate (DBBP), or lard oil (DOE-RL 1991). The

Step 1 – State the Problem

solvent that was discharged to the soil column also contained dibutyl phosphate (DBP), monobutyl phosphate (MBP), and phosphoric acid, which are degradation products of TBP. The organic solutions were periodically discharged to the predominantly water-wetted soil column in small batches (100 to 200 L [26.4 to 52.8 gal]).

The organic solutions were approximately 4% to 8% of the total volume of liquid waste discharged to the disposal facilities. From 1955 to 1973, approximately 13.2 million L (34.8 million gal) of aqueous wastewater were discharged to the three primary disposal sites. The aqueous stream consisted of acidic, high-salt (sodium nitrate) wastewater containing the organic solutions in saturated amounts (<1%). Therefore, carbon tetrachloride was introduced to the vadose zone as an aqueous phase and also as DNAPL (Rohay 2001).

1.6.7 Burial Ground Disposal of Carbon Tetrachloride-Containing Wastes

The 200 West Area burial grounds consist of two low-level waste management areas (LLWMAs), referred to as LLWMA #3 and LLWMA #4. Each LLWMA contains burial grounds that received waste from the Z Plant complex. Because historical records rarely include the hazardous constituents of the waste, the volume of carbon tetrachloride disposed to individual burial grounds is not documented. However, documents and process records summarizing disposal activities state that oils, organics, TBP, DBBP, and carbon tetrachloride were disposed at both LLWMA #3 (218-W-3, 218-W-3A, 218-W-3A-E, and 218-W-5) and LLWMA #4 (218-W-4C) prior to 1988 (Last et al. 1989).

Miscellaneous wastes containing carbon tetrachloride (e.g., rubber gloves, rags, paper, spent solvent, and cutting oils) no longer usable within the Z Plant complex were frequently shipped to the 200 West Area burial grounds for storage. The quantity of miscellaneous wastes containing carbon tetrachloride sent to storage and/or disposed at the burial grounds decreased in 1962 with the startup of the Contaminated Waste Recovery Facility or waste incinerator located in the 232-Z Building. At the Contaminated Waste Recovery Facility, the miscellaneous wastes containing carbon tetrachloride were sent through a chopper and incinerated at 700°C to 800°C (1,292°F to 1,444°F). The resulting ash was packaged in lard cans, placed in drums, and then sent to the burial grounds, or the ash was leached for residual plutonium and then packaged and sent to burial grounds. The T-01 Trench at the 218-W-4C Burial Ground received approximately 500 cans of ash in the early 1980s.

Tables 1-1 through 1-4 identify the DQO scoping team members, workshop team members, integration team members, and key decision makers, respectively.

Step 1 – State the Problem**Table 1-1. DQO Scoping Team Members.**

Name	Organization	Area of Expertise (Role)
Surajit Amrit	BHI, Environmental Technologies	Chemical Engineering
Janet Badden	CHI, Regulatory Support/ Environmental Science	Regulatory
Roy Bauer	CHI, Environmental Engineering	DQO Workbook/Facilitator
Bruce Ford	BHI, Site Assessments	200 Area Remedial Action Task Manager
Greg Gibbons	BHI, Radiological Control Engineering	Radiological Control Engineering
John Ludowise	CHI, Environmental Engineering	200-PW-1 Task Lead, Process Knowledge
Dave St. John	CHI, Sample/Data Management	Sampling Data Management/Site Sampling History
Jim Sharpe	CHI, Regulatory Support/ Environmental Science	Cultural/Biological Issues
Kevin Singleton	CH2M HILL, Inc.	Geosciences Technical Staff, Author
Rich Weiss	CHI, Sample/Data Management	Radiochemical and Analytical, Data Management
Curt Wittreich	CHI, Environmental Engineering	200 Area Remedial Action Lead
Michelle Yates	CHI, Environmental Engineering	Process Chemistry, Technical Staff, Author

BHI = Bechtel Hanford, Inc.

CHI = CH2M HILL Hanford, Inc.

Table 1-2. DQO Workshop Team Members. (2 Pages)

Name	Organization	Area of Expertise (Role)
Surajit Amrit	BHI, Environmental Technologies	Sample Collection, Liquid Vapor Equilibrium
Kim Anselm	CHI, Office Services	Project Assistant/Document Control
Janet Badden	CHI, Regulatory Support	Regulatory Compliance
Roy Bauer	CHI, Environmental Engineering	DQO Facilitator/Workbook
Bruce Ford	BHI, Environmental Leads	200 Area Remedial Action Task Manager
Greg Gibbons	BHI, Radiological Control Engineering	Environmental Radiological Engineering
John Ludowise	CHI, Environmental Engineering	CHI Project Lead
Virginia Rohay	CHI Geosciences/Modeling	Task Lead, Technical Expert
Jim Sharpe	CHI Environmental Engineering	Scoping - Cultural Resources

Step 1 – State the Problem**Table 1-2. DQO Workshop Team Members. (2 Pages)**

Name	Organization	Area of Expertise (Role)
Kevin Singleton	CH2M HILL, Inc., Geosciences/Modeling	Scoping – 200 Area Geology
Alta Turner	CH2M HILL, Inc.	Statistician
Rich Weiss	CHI, Sample/Data Management	Analytical Laboratory
Curt Wittreich	CHI, Environmental Engineering	CHI 200 Area Project Lead
Michelle Yates	CHI, Environmental Engineering	Scoping – 200 Area Processes/Chemistry

Table 1-3. DQO Integration Team Members.

Name	Organization	Area of Expertise (Role)
George Last	PNNL	Technical Staff
Mart Oostrom	PNNL	Science and Technology Projects
Virginia Rohay	CHI	Integration Contacts
Craig Swanson	CHI	Technical Staff, 200-ZP-1 and 200-ZP-2
Arlene Tortoso	RL	Groundwater Integration

PNNL = Pacific Northwest National Laboratory

RL = U.S. Department of Energy, Richland Operations Office

Table 1-4. DQO Key Decision Makers.

Name	Organization	Area of Expertise (Role)
Dennis Faulk	EPA	EPA OU Manager
Bryan Foley	DOE	DOE Project Manager
Arlene Tortoso	DOE	DOE Project Manager

DOE = U.S. Department of Energy

Table 1-5 lists the key sources of existing documents and data collected from previous investigations that were reviewed by the DQO team.

Step 1 – State the Problem**Table 1-5. Existing Documents and Data Sources
for 200-PW-1 Operable Unit. (4 Pages)**

Reference	Summary
<i>200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program</i> , DOE/RL-98-28, Rev. 0 (DOE-RL 1999)	Provides background geography, process, waste site, COC knowledge, and strategy for the 200 Areas.
<i>200 Areas Waste Sites Handbook</i> , 3 vols., RHO-CD-673 (Maxfield 1979)	Provides waste site descriptions, releases, waste discharge information, and management reports.
<i>1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site</i> , WHC-SD-EN-TI-248, Rev. 0 (Rohay 1994)	Provides data summaries and analytical results from limited field investigations conducted at 216-Z-1A and 216-Z-9. Includes geological information, COPC and COC information, and carbon tetrachloride information.
<i>200-ZP-1 Groundwater Sampling and Analysis Plan/Quality Assurance Plan</i> , BHI-00038, Rev. 1 (BHI 1995a)	Presents the 1995 perimeter of the carbon tetrachloride plume in the vicinity of the 200-ZP-1 OU and identifies the wells that will be sampled for remedial action assessment and to track the plume periphery. Identifies the sampling frequency, analyses to be performed, and the list of wells from which groundwater-level measurements will be collected.
<i>200-ZP-1 IRM Phase II and III Remedial Design Report</i> , DOE/RL-96-07, Rev. 0 (DOE-RL 1996)	Identifies the water-level monitoring network and groundwater sampling network used to monitor groundwater conditions in the vicinity of 200-ZP-1 OU. Some of the wells listed for monitoring are different than those identified in BHI (1995a) because the shape of the carbon tetrachloride plume has changed over time, new wells were installed, etc. Provides computer simulation results.
<i>Hanford Site Groundwater Monitoring for Fiscal Year 2000</i> , PNNL-13404 (PNNL 2001)	Presents groundwater contours and the perimeter of the carbon tetrachloride, chloroform, and trichloroethylene plumes in the vicinity of 200-ZP-1 OU. Also provides maps showing the location of sampled groundwater wells and identifies the frequency at which wells are sampled, depth of well screens, etc.
<i>Fiscal Year 2000 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations</i> , DOE/RL-2000-71 (DOE-RL 2001)	Summarizes the performance of the groundwater treatment system in FY00 and discusses the changes that have been observed in the plume shape and concentration during this reporting period. In summary, contaminants from the high-concentration area have been contained, contaminant mass was removed from the high-concentration portion of the aquifer, and increasing or high concentrations in the four northernmost extraction wells and in nearby monitoring wells indicate that additional dissolved mass is moving toward the pumping centers, away from the center of the plume.
<i>Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997</i> , BHI-01105, Rev. 0 (Rohay 1997)	Provides data on in situ soil vapor samples collected during drilling and on soil vapor concentrations at 216-Z-9, 216-Z-1A, and 216-Z-18.

**Table 1-5. Existing Documents and Data Sources
for 200-PW-1 Operable Unit. (4 Pages)**

Reference	Summary
<i>FY 1993 Wellfield Enhancement Status Report and Data Package for the 200 West Area Carbon Tetrachloride Expedited Response Action</i> , BHI-00105, Rev. 00 (Rohay 1995)	Provides data on in situ soil vapor samples collected during drilling and on soil vapor concentrations at 216-Z-9, 216-Z-1A, and 216-Z-18.
<i>FY93 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Site</i> , WHC-SD-EN-TI-202, Rev. 0 (WHC 1993b)	Provides data on in situ soil vapor samples collected during drilling and on soil vapor concentrations at 216-Z-9, 216-Z-1A, and 216-Z-18.
<i>Final Report for the Remote CCTV Survey of Abandoned Process Effluent Drain Lines 840 and 840D in Support of the 200 West Area Carbon Tetrachloride ERA</i> , WHC-SD-NR-ER-103, Rev. 0 (WHC 1993a)	Discusses camera inspection of buried effluent lines.
<i>Plutonium Finishing Plant Wastewater Stream-Specific Report</i> , WHC-EP-0342, Addendum 8 (Jensen 1990)	Provides process knowledge for PFP, sampling data for 1990 effluent stream to the 216-Z-20, and COC information
<i>The 216-Z-8 French Drain Characterization Study</i> , RHO-RE-EV-46 P (Marratt et al. 1984)	Discusses historical waste site, operational, geological, and COC disposal information.
<i>Distribution of Plutonium and Americium Beneath the 216-Z-1A Crib: A Status Report</i> , RHO-ST-17 (Price et al. 1979)	Provides data summaries and analytical results from limited field investigations at 216-Z-1A. Contains geological information and also COPC and COC information.
<i>Report on Plutonium Mining Activities at 216-Z-9 Enclosed Trench</i> , RHO-ST-21 (Ludowise 1978)	Provides an indication of carbon tetrachloride status during mining operations.
<i>Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench</i> , ARH-2915 (Smith 1973)	Provides data summaries and analytical results of plutonium inventories before removal at 216-Z-9.
<i>Hanford Site Atlas</i> , BHI-01119, Rev. 1 (BHI 1998)	Provides Hanford Site maps.
WIDS reports for 200-PW-1: 216-T-19 Crib, 216-Z-1&2 Cribs, 216-Z-1A Tile Field, 216-Z-3 Crib, 216-Z-9 Trench, 216-Z-12 Crib, 216-Z-18 Crib, 241-Z-361 settling tank, UPR-200-W-103, UPR-200-W-110	Summarizes site names, locations, types, status, site and process descriptions, associated structures, cleanup activities, environmental monitoring description, access requirements, references, regulatory information, and waste information (e.g., type, category, physical state, description, and stabilizing activities).
<i>Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992-September 2000</i> , BHI-00720, Rev. 5 (Rohay 2001)	Provides data summaries and updated results of limited field investigations for the 200 West Area with respect to carbon tetrachloride and selected VOAs.
Description of work documents for the 216-Z-9 Trench, which are currently being developed by the ERC Groundwater/Vadose Zone Integration Project (to be published)	Will provide information on COCs. Will also provide geological and groundwater information regarding carbon tetrachloride and proposed Groundwater Management Project's proposed strategy.

Step 1 – State the Problem**Table 1-5. Existing Documents and Data Sources
for 200-PW-1 Operable Unit. (4 Pages)**

Reference	Summary
<i>Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/Technetium Plumes in the 200 West Area: 1994 to 1999 Update</i> , BHI-01311, Rev. 0 (Swanson et al. 1999)	Provides geological and groundwater information.
<i>DNAPL Investigation Report</i> , BHI-00431, Rev. 0 (BHI 1995b)	Provides geological information.
<i>216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium</i> , RHO-ST-44 (Kasper 1982)	Provides historical waste site, operational, geological, and COC disposal information regarding pipelines to waste site and leaks.
<i>Hanford Site Groundwater Monitoring for Fiscal Year 1998</i> , PNNL-12086 (PNNL 1999)	Provides groundwater annual report information.
PNLATLAS/LG-ARCHV/200 East and West Areas	Database for geophysical logging.
<i>Z Plant Liquid Waste Disposal Through the 241-Z Vault</i> , ARH-CD-323 (ARH 1976)	Provides historical waste site, operational, geological, and COC disposal information.
<i>Hanford Site-wide Groundwater Remediation Strategy</i> , DOE/RL-94-95, Rev. 1 (DOE-RL 1997a)	Provides groundwater and geological information.
<i>History and Stabilization of the Plutonium Finishing Plant (PFP) Complex, Hanford Site</i> , HNF-EP-0924 (Gerber 1997)	Provides historical account of process operations information for Z Plant and ancillary facilities, and feed process modifications at REDOX, PUREX, T, and B Plants. Discusses problems encountered, solutions implemented, chemical used, an overview of each processes' daily activities, building construction, functions, maintenance, and sampling, laboratory, and disposal activities.
<i>200 Areas Disposal Sites for Radioactive Liquid Wastes</i> , ARH-947 (Curren 1972)	Discusses waste site and COC information.
<i>Waste Site Grouping for 200 Areas Soil Investigations</i> , DOE/RL-96-81, Rev. 0 (DOE-RL 1997b)	Summarizes site name, location, type status, site and process descriptions, known and suspected contamination, preliminary contaminant distribution conceptual model, site conditions that may affect COC fate and transport, COC mobility in Hanford Site soils, COC distribution and transport to groundwater, and hazards associated with COCs. Identifies soil porosity information for each waste site.
<i>Z Plant Source Aggregate Area Management Study Report</i> , DOE/RL-91-58, Rev. 0 (DOE-RL 1992)	Provides soil and geological information, COPC information, process history, and geophysical logging information.
HEIS database	Provides well information and sampling data.

**Table 1-5. Existing Documents and Data Sources
for 200-PW-1 Operable Unit. (4 Pages)**

Reference	Summary
Discussions with Mr. Thurman D. Cooper, PFP Chemist	Identified historical process and operation information and COPC listings.
Discussions with Mr. David A. Dodd, PFP Chemist	Identified historical process and operation information and COPC listings.
Site visit notes	Provided information on general site conditions.
Drawings	Provide construction "as-built" drawings of individual waste sites.

COC = contaminant of concern
COPC = contaminant of potential concern
ERC = Environmental Restoration Contractor
FY = fiscal year
HEIS = Hanford Environmental Information System
PUREX = Plutonium-Uranium Extraction (Facility)
REDOX = Reduction-Oxidation (Facility)
WIDS = Waste Information Data System

1.7 CONTAMINANTS OF CONCERN

Process knowledge indicates that the 200-PW-1 OU waste streams were predominantly liquid effluent discharges from the plutonium purification by solvent extraction processes performed at Z Plant. In general, the waste generated can be described as plutonium- and organic-rich, discharged mainly from the Recovery of Uranium and Plutonium by Extraction (RECUPLEX) process and PRF processes. Additional waste streams from PFP operations included the rubber glove (RG) line, remote mechanical operations for "A" and "C" lines (RMA and RMC), the americium recovery process, and laboratory waste. The waste contained inorganic anions and cations, acids, and large amounts of organic waste with high levels of plutonium and americium-241, moderate amounts of uranium, and lower amounts of fission products. Of the many constituents used in the extraction process, carbon tetrachloride is the sole interest of this dispersed plume DQO process because it has migrated into the vadose zone beyond the waste site boundaries and has been detected in the groundwater underlying most of the 200 West Area. The 200-PW-1 OU representative waste site DQO summary report addressed the other contaminants (Bauer 2002).

The DQO process establishes a systematic methodology for identification of the contaminants of concern (COCs) for each project. This is accomplished using a series of tables that identify all contaminants of potential concern (COPCs), followed by a table of contaminants that may be excluded based on half-life or other physical properties, resulting in a table with the final list of COCs. However, because this DQO process is focused on carbon tetrachloride, the normal COPC/COC development process has been curtailed by assigning carbon tetrachloride as the only COC for this study.

Step 1 – State the Problem

Although carbon tetrachloride is the primary focus of this DQO process, the identification of carbon tetrachloride degradation products and co-contaminants (discharged as waste with the carbon tetrachloride) may indicate the release mode and/or presence of carbon tetrachloride and may support remedial decision making.

Carbon tetrachloride degrades in the environment by hydrolysis and anaerobic biodegradation. The following degradation products are formed:

- Chloroform (trichloromethane)
- Methylene chloride (dichloromethane)
- Methyl chloride (monochloromethane)
- Methane.

The list of co-contaminants was derived from facility process knowledge and information regarding waste discharge operations at the Z Plant complex. The co-contaminants include the following:

- DBP
- DBBP
- Fluoride
- Lard oil
- MBP
- Nitrate/nitrite
- Phosphate
- TBP
- Plutonium isotopes.

The co-contaminants are nonvolatile and would only be detected in soil samples. The degradation products are vapors, and would generally be detected in vapor analyses. Chloroform is the first degradation product of carbon tetrachloride and would be the most likely detected of the listed degradation products.

1.8 POTENTIAL ARARS AND PRGS

Table 1-6 defines the potential ARARs and preliminary remediation goals (PRGs) for each of the COCs.

Table 1-6. List of Potential ARARs and PRGs.

COCs	Preliminary ARARs	PRGs
Carbon tetrachloride	N/A ^a	

^a The project objectives for this DQO effort are defined in Section 1.3 and are focused on locating and characterizing active vadose zone sources of carbon tetrachloride contamination to groundwater, developing the conceptual contaminant distribution model, and enhancing the understanding of the mechanisms that lead to groundwater contamination. The ARARs and PRGs do not apply to this DQO process because they do not support resolution of the decisions in this study. The decisions in this study will be resolved by modeling, engineering evaluations, and/or simply by detection of continuing sources to groundwater. Therefore, this table is not used in this DQO process. The ARARs/PRGs related to worker health and safety and ecological protection will be included in a subsequent DQO process.

N/A = not applicable.

1.9 GENERAL EXPOSURE SCENARIOS

Table 1-7 lists the general exposure scenarios.

Table 1-7. General Exposure Scenarios.

Scenario No.	General Exposure Scenario Description
All	N/A ^a

^a The project objectives for this DQO are defined in Section 1.3 and are focused on locating and characterizing active vadose zone sources of carbon tetrachloride contamination to groundwater, developing the conceptual contaminant distribution model(s), and enhancing the understanding of the mechanisms that lead to groundwater contamination. This study does not address compliance with ARARs for occupational workers or ecological protection. Consequently, general exposure models have not been developed for this DQO process because they do not support resolution of the decisions in this study.

N/A = not applicable.

1.10 MILESTONE DATES

Table 1-8 provides the regulatory milestones and regulatory drivers associated with this project.

Table 1-8. Regulatory Milestones.

Milestone	Due Date	Regulatory Driver
M-13-26	December 31, 2001	Tri-Party Agreement milestone to submit 200-PW-1 Plutonium Rich/Organic Rich Waste Group work plan (Draft A) to EPA

Tri-Party Agreement = *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1998)

Step 1 – State the Problem

1.11 PROJECT SCHEDULE

The project schedule and the drivers are listed in Table 1-9.

Table 1-9. Project Schedule.

Activity	Due Date	Driver
Internal DQO workshop	June 22, 2001	DQO schedule
External DQO briefing	July 27, 2001	
Issue DQO summary report	May 2002	DQO documentation

1.12 PRELIMINARY CONCEPTUAL CONTAMINANT DISTRIBUTION MODEL

Table 1-10 provides relevant background information.

**Table 1-10. Preliminary Conceptual Contaminant Distribution Model Discussion.
(4 Pages)**

Contaminant Releases

Disposal of large quantities of carbon tetrachloride to the soil column began in 1949 and ceased in 1973. Plutonium-rich/organic-rich waste streams associated with the plutonium recovery processes at the Z Plant complex are the primary contributors of carbon tetrachloride contamination in the 200 West Area. Releases from Z Plant complex have created secondary releases, which are mainly the liquid waste receiving (i.e., cribs and trenches) and the unplanned release sites associated with the 200-PW-1 OU. The 200-PW-1 waste sites are the known carbon tetrachloride releases to the environment. Furthermore, characterization data and process knowledge suggest that other undocumented releases of carbon tetrachloride exist. These potential releases modes include non-waste and waste-related streams in the Z Plant complex, burial grounds, and pipelines that have not been documented as contributing carbon tetrachloride to the environment.

Effluent and other wastes containing carbon tetrachloride were mainly disposed to the soil column at liquid waste receiving sites. A total of 363,000 to 580,000 L (577,000 to 922,000 kg) of carbon tetrachloride was released to the soil column. The carbon tetrachloride released was usually mixed 50% to 85% (by volume) with TBP, DBBP, or lard oil and actinide-bearing liquids. The wastes were released periodically to a water-wetted soil column in small, 100- to 200-L (26.4- to 52.8-gal) batches. Effluent containing carbon tetrachloride as DNAPL made up 4% to 8% of the total volume of liquid waste discharged to 200-PW-1 sites. Because of the low solubility of carbon tetrachloride, less than 1% was dissolved in aqueous wastes. The aqueous waste streams consisted of acidic, high-salt (sodium nitrate) wastes with nitric acid, fluorides, nitrates, and phosphates. Thus, carbon tetrachloride was discharged to the soil column as an aqueous phase and as DNAPL.

The largest known quantities of carbon tetrachloride (as organic waste, aqueous effluent, or both) were discharged to seven liquid waste receiving sites: 216-T-19, 216-Z-1&2, 216-Z-1A, 216-Z-3, 216-Z-9, 216-Z-12, and 216-Z-18. Over 95% of the known quantity of carbon tetrachloride discharge to the soil column came from these sites. The remaining inventory of known carbon tetrachloride is attributed to other receiving sites and unplanned releases (i.e., accidental releases and spills). The 216-Z-9 site is the known worst-case site in terms of the inventory of carbon tetrachloride released.

**Table 1-10. Preliminary Conceptual Contaminant Distribution Model Discussion.
(4 Pages)**

Groundwater, vapor extraction, and limited soil data are used to assess the distribution of carbon tetrachloride in the subsurface. These data and the historical information regarding site operations suggest that unknown releases of carbon tetrachloride may be contributing to subsurface contamination. Potential releases include pipelines under the Z Plant complex and pipelines that extend to receiving waste sites, former drum storage areas for carbon tetrachloride, the burial ground, and other liquid waste receiving sites in the 200 West Area. Available data suggest that pipelines carrying process waste may have leaked, and hot spots of groundwater contamination may be associated with a source within the Z Plant complex and/or burial grounds. Gravel storage pads at the Z Plant complex used to store carbon tetrachloride during operations may also have released carbon tetrachloride; however, a significant portion of releases from this area was likely dispersed to the atmosphere because of the volatility of carbon tetrachloride.

Physical Setting

The thickness of the vadose zone ranges from about 40.2 to 102 m (132 to 337 ft) in the 200 West Area. The thickness of the vadose zone also corresponds to the depth to the water table. In the Z Plant area, the vadose zone is approximately 68 m (222 ft) thick and can be broadly divided into an upper and lower gravel and sand interval (Hanford formation vadose zone), a silty sand interval (Plio-Pleistocene unit), and a lower gravel and sand interval (Ringold Formation). The Plio-Pleistocene unit appears to be a major barrier to the vertical transport of water and contaminants in the subsurface. The surface of this unit is very irregular in the Z Plant area. Beneath 216-Z-9, the Plio-Pleistocene unit slopes to the southeast; approximately 200 m (656 ft) to the west beneath the Z Plant complex, the surface of the Plio-Pleistocene unit slopes to the west. The thickness of the vadose zone is currently expanding at a rate of 0.5 m (1.6 ft) each year. The increasing thickness corresponds to a decline in the elevation of the water table due to reductions in wastewater discharges to the ground that have occurred since 1984.

Groundwater in the unconfined aquifer flows from areas where the water table is high (i.e., west of the Hanford Site) to areas where the water table is low (i.e., near the Columbia River). Groundwater near the Z Plant complex generally flows from west to east and is heavily influenced by ongoing pump-and-treat activities. A small groundwater mound is associated with the injection wells, and a small region of drawdown is associated with extraction wells in and adjacent to the high concentration portion of the plume (>4,000 ppb).

Nature and Extent of Contamination

Carbon tetrachloride is present throughout the vadose zone within a 0.2-km² area near the Z Plant complex. This small zone of contamination is defined by soil and vapor samples collected near sites 216-Z-1A, 216-Z-9, 216-Z-12, and 216-Z-18. Limited data are available to evaluate the lateral extent of contamination outside of these waste sites; however, carbon tetrachloride is assumed to extend to the boundary of the 200 West Area.

The vapor pressure of carbon tetrachloride suggests that the vapor phase of this contaminant is likely distributed widely across the 200 West Area in the vadose zone. Both DNAPL and aqueous phases are expected to be present in the vadose zone (associated with liquid contaminant pathways to the groundwater) and beneath and near the footprint of waste sites. However, subsurface preferential flow pathways could have also caused lateral migration (see the preliminary conceptual contaminant distribution model shown in Figure 1-6).

Sampling performed prior to SVE operations indicated that the highest concentrations of tetrachloride in soil and vapor are consistently located in the vicinity of the 216-Z-9 Trench. Higher concentrations are also consistently detected in the proximity of the Plio-Pleistocene unit. Maximum vapor concentrations exceeded 10,000 ppmv above the Plio-Pleistocene unit at the 216-Z-9 Trench between 1991 and 1993. In contrast, carbon tetrachloride concentrations were an order of magnitude lower at similar depths beneath the 216-Z-1A, 216-Z-18, and 216-Z-12 sites.

**Table 1-10. Preliminary Conceptual Contaminant Distribution Model Discussion.
(4 Pages)**

Vapor sampling conducted in 1999-2000 during a temporary suspension of SVE operations provides a relative indication of the distribution of carbon tetrachloride vapors currently in the vadose zone in the area of the carbon tetrachloride disposal sites. The data indicate that vapor concentrations range between 5 and 69 ppmv over most of the vadose zone; however, the highest concentration (561 ppmv) was detected near the Plio-Pleistocene unit. The observed distribution of vapors in the subsurface separates the vadose zone into high- and low-concentration areas and suggests that the Plio-Pleistocene unit is the most likely accumulation zone for the carbon tetrachloride.

Soil samples were collected throughout the vadose zone in 13 boreholes near the carbon tetrachloride waste sites in 1992 and 1993. Carbon tetrachloride concentrations in these wells rarely exceeded 2 ppm, except near the 216-Z-9 Trench. The maximum detected near the 216-Z-9 Trench was 37.9 ppm; however, as much as 16 ppm were detected 52 m (171 ft) north of the 216-Z-9 Trench. This suggests the possibility of extensive lateral spreading or an undocumented release. In contrast, data obtained in the 1970s from the 216-Z-1A Tile Field suggest limited spreading (less than 9 m [30 ft]). The highest concentrations detected in soil samples were associated with the Plio-Pleistocene unit. Limited data have been collected within the footprints of the waste sites known to have received carbon tetrachloride.

Carbon tetrachloride above the maximum contaminant level of 5 ppb is present in the unconfined aquifer beneath most of the 200 West Area. The plume covers an area greater than 11 km² (4.4 mi²). The 200-ZP-1 groundwater pump-and-treat system is containing the carbon tetrachloride within the 2,000-µg/L contour. Between August 1994 and September 2001, this system has removed approximately 5,800 kg of carbon tetrachloride, which is 91% to 274% of the mass initially estimated in 1990 to be contained within the 2,000-µg/L contour. The persistence of the carbon tetrachloride concentrations implies that the initial mass calculation was incorrect (e.g., because of greater depth distribution), that the K_d is greater than assumed, and/or possibly the presence of a continuing source of carbon tetrachloride (residual or DNAPL). The FY00 groundwater plume map shown in Figure 1-3 shows several high-concentration groundwater plumes located near the center of the map.

The most contaminated portion of the groundwater plume (>4,000 ppb) is located beneath the Z Plant complex and extends radially about 500 m (1,640 ft). The maximum concentration of 6,600 ppb was detected in groundwater monitoring well 299-W15-16. Because this well is not located near a known release site and because the concentrations in this well have been consistently high, an active source of groundwater contamination may be present in the vicinity of the well.

Contaminant Flow and Transport

Effluent was discharged to the soil column at select liquid waste receiving sites in the 200-PW-1 OU. Undocumented releases may have also occurred from pipelines and to other waste sites. Release modes are shown in Figure 1-5. The effluent consisted of carbon tetrachloride in aqueous and DNAPL phases. Volatilization of carbon tetrachloride from aqueous and non-aqueous phase liquids also results in a vapor phase of the contaminant in the vadose zone.

After discharge, liquids (i.e., water, aqueous carbon tetrachloride, and DNAPL) infiltrate the underlying soil based on their respective hydraulic gradients. Moisture and contaminants move vertically beneath waste site by uniform^a and unstable^b flow. Little or no lateral spreading has occurred, unless a preferential flow^c is associated with the Plio-Pleistocene unit. The conclusion of vertical flow is based on numerical simulation in Last and Rohay (1993), Piepho (1996), and PNL (1994). Work performed to assess the lateral extent of contamination at the 216-Z-1A Tile Field suggests the transport of liquids is predominately vertically (Price et al. 1979). Vapors can move in the subsurface by molecular diffusion and by density-driven advective flow.

Step 1 – State the Problem

**Table 1-10. Preliminary Conceptual Contaminant Distribution Model Discussion.
(4 Pages)**

As carbon tetrachloride moves through the soil column, a fraction of the compound is held as residual liquid in the soil pore spaces. Retention of carbon tetrachloride is caused by capillary forces, reversible and nonreversible sorption to soil, and entrapment in dead-end pore spaces. Conca and Wright (1992) indicate that the retention of DNAPL is about half that of aqueous carbon tetrachloride. Numerical modeling suggests that 66% to 90% of the carbon tetrachloride released at the worst-case site (216-Z-9) was retained in the soil column after discharge. Leaking sanitary and raw water pipelines in the PFP area may mobilize residual liquid in the subsurface and may impact groundwater. Pipelines in the PFP areas are shown in Figure 1-7.

Volatilization occurs from all phases of carbon tetrachloride because it has a relatively moderate vapor pressure (77 mm of mercury). The vapor phase is initially present within the soil pore spaces; however, the vapors can also partition into soil moisture and adsorbed phases. If soil vapors equilibrate with water in the vadose zone, dissolved carbon tetrachloride may be transported to the water table. Carbon tetrachloride may also volatilize from the dissolved groundwater plume.

- ^a Uniform matrix flow (i.e., piston flow and wetting-front infiltration) refers to uniform moisture movement through the soil matrix whereby effluent liquids displace the initial water content of the soil. Under piston-like flow conditions, most (if not all) pre-existing water is displaced and moves ahead of the new water-added form above.
- ^b Unstable flow or wetting-front instability refers to flow when water accumulates in and over a fine-grained unit until the thickness of the perched water provides sufficient driving force to allow water to drip into the large pore spaces of the underlying coarse-grain sediments.
- ^c Preferential or structural controlled flow refers to the infiltration flux along the path of least resistance in porous media that is not uniformly distributed. These pathways can be natural (e.g., clastic dikes or Plio-Pleistocene unit) or man-made (e.g., unsealed borehole).

K_d = distribution coefficient

ppm = parts per million

1.13 CONCISE STATEMENT OF THE PROBLEM

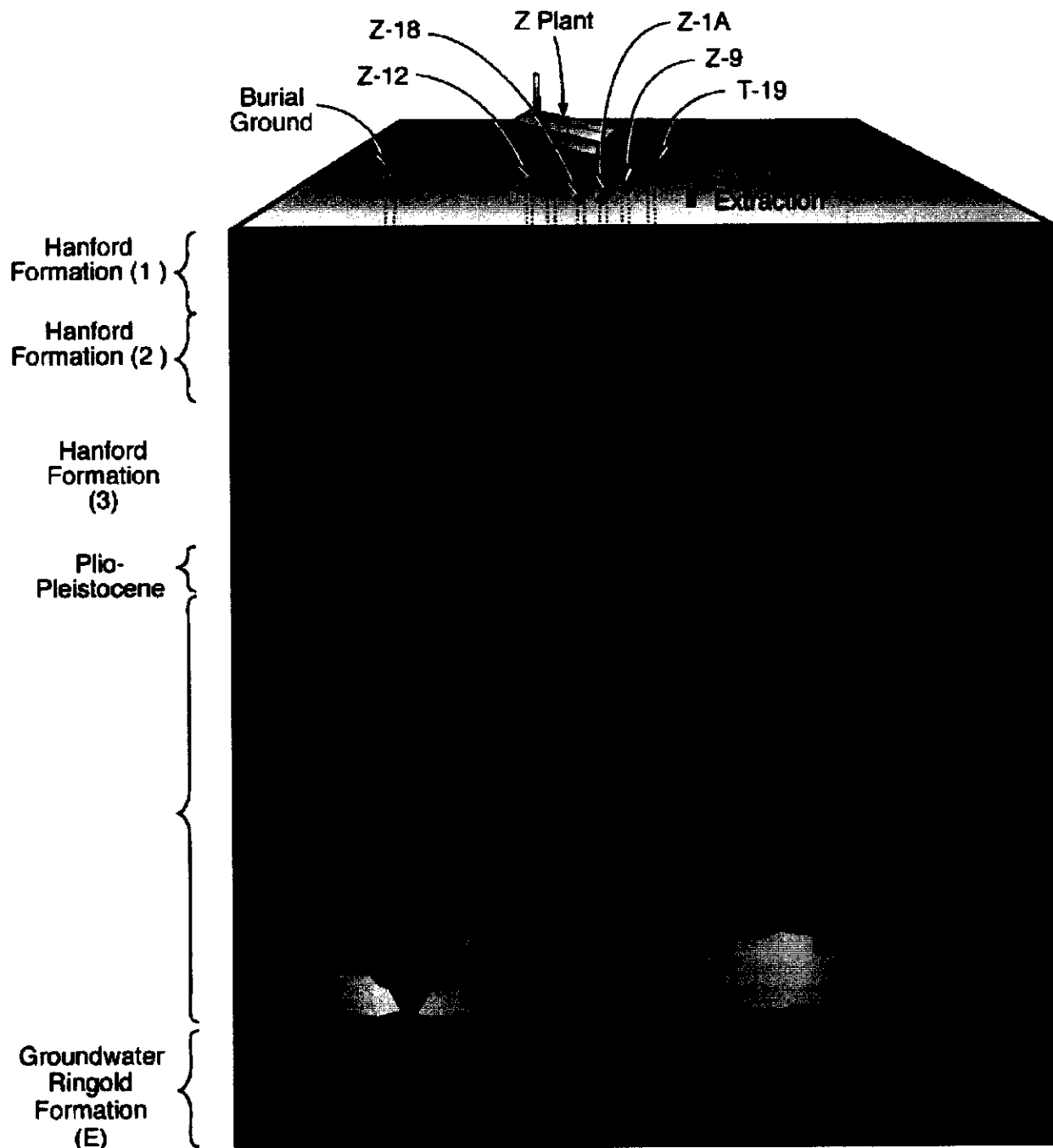
Table 1-11 combines relevant background information into a concise statement of the problem to be resolved.

Table 1-11. Concise Statement of the Problem.

Problem Statement:

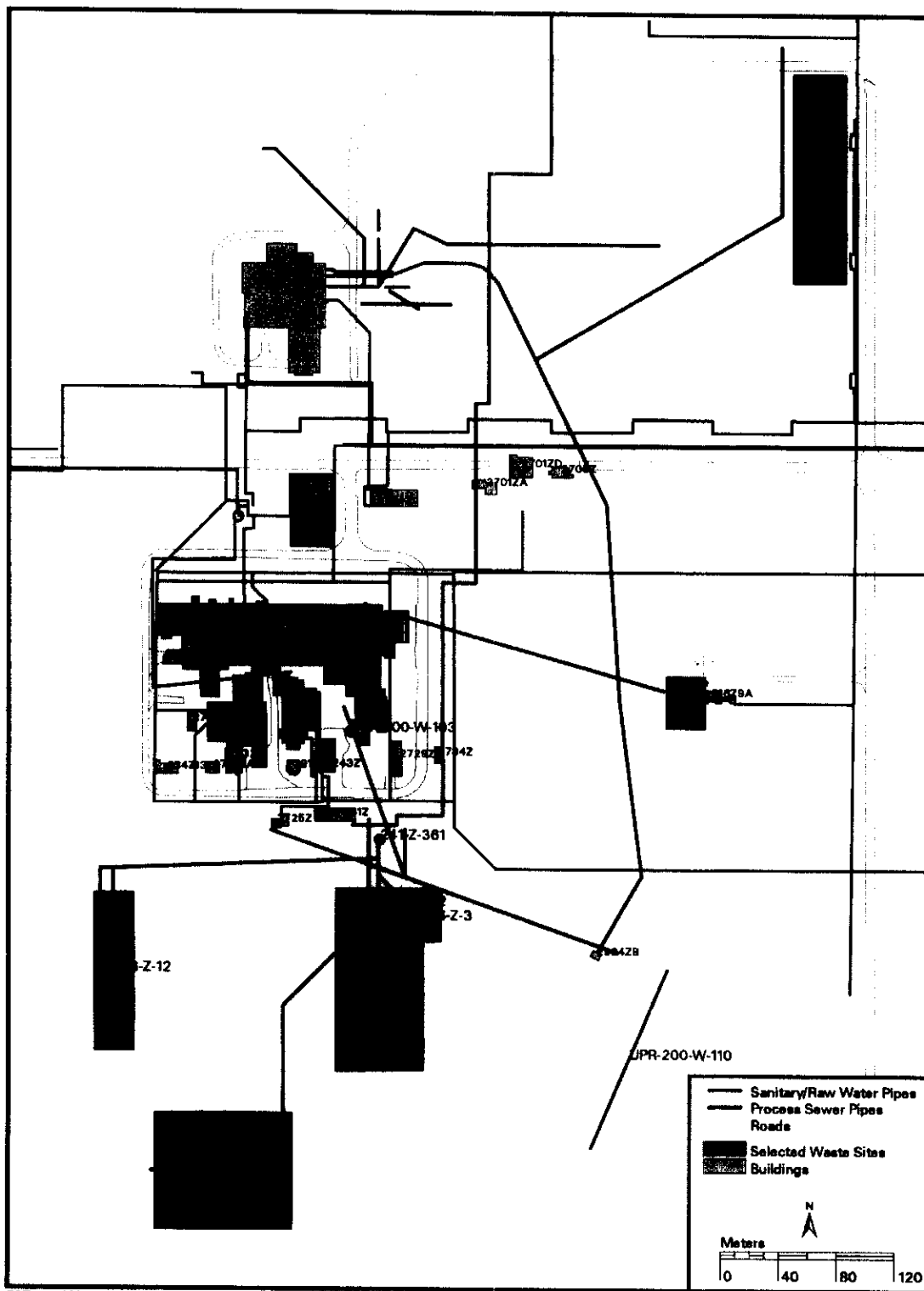
In order to locate and characterize the sources of carbon tetrachloride contamination in the vadose zone that are presently impacting groundwater, as well as the known and suspect release sites with potential to impact groundwater in the future, to provide information for remedial alternative decision making, and to verify and refine the conceptual contaminant distribution model(s), data regarding the vadose zone carbon tetrachloride concentrations are needed.

Figure 1-6. Preliminary Conceptual Contaminant Distribution Model.



E0105135.1b

Figure 1-7. Sanitary, Raw Water, and Process Discharge Pipelines Located Near the Z Plant Complex Release Areas.



2.0 STEP 2 – IDENTIFY THE DECISION

The purpose of DQO Step 2 is to define all of the principal study questions (PSQs) that need to be resolved to address the problems identified in DQO Step 1 and the alternative actions (AAs) that would result from resolution of the PSQs. The PSQs and AAs are then combined into decision statements (DSs) that express a choice among AAs. Table 2-1 presents the task-specific PSQs, AAs, and resulting DSs. This table also provides a qualitative assessment of the severity of the consequences of taking an AA if it is incorrect. This assessment takes into consideration human health and the environment (flora/fauna) and political, economic, and legal ramifications. The severity of the consequences is expressed as low, moderate, or severe.

Table 2-1. Summary of DQO Step 2 Information. (2 Pages)

PSQ-AA #	Alternative Action	Consequences of Erroneous Actions	Severity of Consequences
PSQ #1 – Where are the carbon tetrachloride release sites located in the vadose zone?			
1-1	Evaluate for current impacts to groundwater.	Release sites that are currently impacting groundwater are erroneously not identified.	Severe
1-2	Evaluate for potential future impacts to groundwater.	Release sites with potential to impact groundwater in the future are erroneously not identified.	Severe
1-3	Do not evaluate for current or future impacts.	Release sites that are currently impacting or have potential to impact groundwater in the future are erroneously not identified.	Severe
DS #1 – Determine where the known or suspect carbon tetrachloride release sites are located in the vadose zone and evaluate for current impacts to groundwater, evaluate for potential future impacts to groundwater, or do not evaluate for current or future impacts.			
PSQ #2 – Are the known or suspect carbon tetrachloride release sites in the vadose zone currently impacting groundwater?			
2-1	Evaluate expansion of the vapor extraction system to enhance the expedited response action.	Portions of the vadose zone could be needlessly remediated.	Low
2-2	Evaluate remedial alternatives in a FS.	The 200 West Area may be inappropriately remediated, resulting in unnecessary expenditure of funds.	Low
DS #2 – Determine if the known or suspect carbon tetrachloride release sites in the vadose zone are currently impacting groundwater and evaluate expansion of the vapor extraction system to enhance the expedited response action, or evaluate remedial alternatives in a FS.			

Step 2 – Identify the Decision

BHI-01544

Rev. 0

Table 2-1. Summary of DQO Step 2 Information. (2 Pages)

PSQ-AA #	Alternative Action	Consequences of Erroneous Actions	Severity of Consequences
PSQ #3 – Do the known or suspect carbon tetrachloride release sites within the vadose zone have the potential to impact groundwater in the future?			
3-1	Evaluate expansion of the vapor extraction system to enhance the expedited response action.	Portions of the vadose zone could be needlessly remediated.	Low
3-2	Evaluate remedial alternatives in a FS.	The 200 West Area may be inappropriately remediated, resulting in unnecessary expenditure of funds.	Low
DS #3 – Determine if known or suspect carbon tetrachloride release sites within the vadose zone have the potential to impact groundwater in the future and evaluate expansion of the vapor extraction system to enhance the expedited response action, or evaluate remedial alternatives in a FS.			

3.0 STEP 3 – IDENTIFY THE INPUTS TO THE DECISION

The purpose of DQO Step 3 is to identify the types of data needed to resolve each of the DSs identified in DQO Step 2. The data may already exist or may be derived from computational or surveying/sampling and analysis methods. Analytical performance requirements (e.g., practical quantitation limit [PQL], precision, and accuracy) are also provided in this step for any new data needed to be collected.

3.1 BASIS FOR SETTING THE PRELIMINARY ACTION LEVEL

The preliminary action level is the threshold value that provides the criterion for choosing between AAs. Table 3-1 identifies the basis (i.e., regulatory threshold or risk-based) for establishing the preliminary action level for each of the COCs. The numerical value for the action level is defined in DQO Step 5.

Table 3-1. Basis for Setting Preliminary Action Level.

DS #	COCs	Basis for Setting Preliminary Action Level	Preliminary Action Levels
1, 2, and 3	Carbon tetrachloride	Carbon tetrachloride vapor concentrations in the upper vadose zone ^a , Plio-Pleistocene, or deep vadose zone ^b .	Modeling and/or engineering judgment, based on detected values
		Carbon tetrachloride total concentrations in the upper vadose zone ^a , Plio-Pleistocene, or deep vadose zone ^b .	Modeling and/or engineering judgment, based on detected values
		Carbon tetrachloride in free liquid accumulations in the upper vadose zone ^a , Plio-Pleistocene formation, or deep vadose zone ^b that can migrate toward groundwater.	Any aqueous streams or free liquid accumulations

^a Upper vadose zone is from ground surface to the top of the Plio-Pleistocene formation.

^b Deep vadose zone is from beneath the Plio-Pleistocene formation to the top of the saturated zone.

3.2 INFORMATION REQUIRED TO RESOLVE DECISION STATEMENTS

Table 3-2 specifies the information (data) required to resolve each of the DSs identified in Table 2-1 and identifies whether the data already exist. For the data that are identified as existing, the references for the data have been provided with a qualitative assessment as to whether or not the data are of sufficient quality to resolve the corresponding DS.

Table 3-2. Required Information and References. (4 Pages)

DS #	Required Information Category	Do Data Exist? Y/N	Reference	Are Available Data of Sufficient Quality and Quantity to Support RI/FS Process? (Y/N)	Are Additional Data Required to Support RI/FS Process? (Y/N)
1, 2, and 3	Soil vapor concentrations in vicinity of known release sites 216-Z-9, 216-Z-1A, and 216-Z-18	Y	<i>Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992-September 2000</i> , BHI-00720, Rev. 5 (Rohay 2001). Provides SVE data summaries, monthly soil vapor monitoring results, and updated results of limited field investigations for the 216-Z-1A, 216-Z-9, and 216-Z-1A waste sites with respect to carbon tetrachloride and selected VOAs.	N ^a	Y
			<i>Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997</i> , BHI-01105, Rev. 0 (Rohay 1997). Provides soil vapor monitoring results for the 216-Z-1A, 216-Z-9, and 216-Z-1A Cribs and in situ soil vapor sampling results during drilling of selected wells in the vicinity of the cribs.	N ^a	Y
			<i>FY 1993 Wellfield Enhancement Status Report and Data Package for the 200 West Area Carbon Tetrachloride Expedited Response Action</i> , BHI-00105, Rev. 00 (Rohay 1995). Provides in situ soil vapor sampling results during drilling of selected wells in the vicinity of the cribs.	N ^a	Y
			<i>FY93 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Site</i> , WHC-SD-EN-TI-202, Rev. 0 (WHC 1993b). Provides in situ soil vapor sampling results during drilling of selected wells in the vicinity of the cribs.	N ^a	Y

Table 3-2. Required Information and References. (4 Pages)

DS #	Required Information Category	Do Data Exist? Y/N	Reference	Are Available Data of Sufficient Quality and Quantity to Support RI/FS Process? (Y/N)	Are Additional Data Required to Support RI/FS Process? (Y/N)
1, 2, and 3	Soil vapor concentrations in vicinity of known release sites 216-Z-9, 216-Z-1A, and 216-Z-18	Y	<i>Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume</i> , DOE/RL-91-32, Draft B (DOE-RL 1991). Provides summary of chlorinated hydrocarbon “hits” during drilling of RCRA wells in the 200 West Area between 1987 and 1991.	N ^a	Y
			<i>FY92 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Site</i> , WHC-SD-EN-TI-063, Rev. 0 (WHC 1992). Provides summary of chlorinated hydrocarbon “hits” during drilling of RCRA wells in the 200 West Area between 1991 and 1992.	N ^a	Y
			<i>Residual DNAPL Source Evaluation Using Concentration Rebound Data</i> (Riley 1998). Evaluates potential residual carbon tetrachloride for rebound data from 216-Z-9, as discussed by Rohay (1997).	N ^a	Y
	Soil nonradiological sample data at known release sites 216-Z-9, 216-Z-1A, and 216-Z-18	Y	<i>Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992-September 2000</i> , BHI-00720, Rev. 5 (Rohay 2001). Provides data summaries and updated results of limited field investigations for the 200 West Area with respect to carbon tetrachloride and selected VOAs.	N ^a	Y

Table 3-2. Required Information and References. (4 Pages)

DS #	Required Information Category	Do Data Exist? Y/N	Reference	Are Available Data of Sufficient Quality and Quantity to Support RI/FS Process? (Y/N)	Are Additional Data Required to Support RI/FS Process? (Y/N)
1, 2, and 3	Soil nonradiological sample data at known release sites 216-Z-9, 216-Z-1A, and 216-Z-18	Y	<i>1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford</i> , WHC-SD-EN-TI-248, Rev. 0 (Rohay 1994). Provides data summaries and results from limited field investigations at 216-Z-1A and 216-Z-9.	N ^a	Y
N/A	Groundwater data	Y	<i>DNAPL Investigation Report</i> , BHI-00431, Rev. 0 (BHI 1995b). Provides DNAPL data for well 299-W15-32 drilled near the 216-Z-9 Trench.	N/A ^b	N/A ^b
			<i>Hydrostratigraphy and Recharge Distributions from Direct Measurements of Hydraulic Conductivity Using the UFA Method</i> , PNL-9424 (PNL 1994). Presents results of physical property analyses (i.e., saturation, hydraulic conductivity, pore volume, water content, particle size, mineralogy, and density) from samples collected at wells near 216-Z-9 and 216-Z1A in 1992 and 1993.	N/A ^b	N/A ^b
			<i>1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford</i> , WHC-SD-EN-TI-248, Rev. 0 (Rohay 1994). Provides data summaries and results from limited field investigations at 216-Z-1A and 216-Z-9.	N/A ^b	N/A ^b
			<i>Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/Technetium Plumes in the 200 West Area: 1994 through 1999 Update</i> , BHI-01311, Rev. 0 (Swanson et al. 1999).	N/A ^b	N/A ^b
			<i>Hanford Site Groundwater Monitoring for Fiscal Year 2000</i> , PNNL-13404 (PNNL 2001).	N/A ^b	N/A ^b

Table 3-2. Required Information and References. (4 Pages)

DS #	Required Information Category	Do Data Exist? Y/N	Reference	Are Available Data of Sufficient Quality and Quantity to Support RI/FS Process? (Y/N)	Are Additional Data Required to Support RI/FS Process? (Y/N)
N/A	Groundwater data	Y	<i>Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume, DOE/RL-91-32, Draft B (DOE-RL 1991).</i>	N/A ^b	N/A ^b
N/A			<i>Fiscal Year 2000 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations, DOE/RL-2000-71, Rev. 0 (DOE-RL 2001).</i>	N/A ^b	N/A ^b

^a The referenced data is meaningful to the RI/FS process. However, the data may not conform to the sampling methods or spatial coverage requirements of the sampling design for this DQO effort. Therefore, additional data is required.

^b Groundwater data will not resolve the decisions identified in DQO Step 2 or validate a vadose zone preliminary conceptual contaminant distribution model. Therefore, the entries in the last two columns are shown as "N/A."

N/A = not applicable

RCRA = Resource Conservation and Recovery Act of 1976

Step 3 – Identify the Inputs to the Decision

3.2.1 Data Gap Analysis

As noted in Table 3-2, carbon tetrachloride vapor, total concentration, and groundwater data have been collected from the region around the Z Plant complex. Nevertheless, significant data gaps exist that must be filled. The conclusion, therefore, is that the available data can possibly support the RI/FS process, but a unique sampling design must be developed to resolve the DQO decisions. The verification/refinement of the conceptual contaminant distribution model would require acquisition of data throughout the entire vadose zone.

3.3 COMPUTATIONAL AND SURVEY/ANALYTICAL METHODS

Table 3-3 identifies the DSs where existing data either do not exist or are of insufficient quality to resolve the DSs. For these DSs, Table 3-3 presents computational and/or surveying/sampling methods that could be used to obtain the required data.

Table 3-3. Information Required to Resolve the Decision Statements.

DS #	Remedial Investigation Variable	Required Data	Computational Methods	Survey/Analytical Methods
2 and 3	Determination of carbon tetrachloride impacts to groundwater from the vadose zone	Carbon tetrachloride vapor and total concentrations in the vadose zone	Transport model to predict groundwater impacts from vadose zone releases. A discussion follows this table on existing models, their suitability for carbon tetrachloride vadose zone modeling, and desirable modeling features.	Vapor sampling, soil sampling

TBD = to be determined

3.3.1 Existing Models

Models have previously been applied to predict fate and transport of carbon tetrachloride in the vadose zone (Piepho 1996) and groundwater (Chiaramonte et al. 1996). Rohay and McMahon (1996) conducted air flow modeling to evaluate the zone of influence of the SVE remediation in the vadose zone. Capture zone analysis has been conducted to evaluate the effects of groundwater pump-and-treat remediation on the aquifer (DOE-RL 1999, 2000, 2001; Borghese et al. 1998). Truex et al. (2001) simulated carbon tetrachloride transport in groundwater to facilitate discussion of characterization and remediation options for the carbon tetrachloride plume among the ITRD participants. Ellerd et al. (1999) conducted numerical modeling to evaluate vapor flow in the vadose zone in response to barometric pressure fluctuations.

Step 3 – Identify the Inputs to the Decision

3.3.2 Applicability of Available Models to the Dispersed Vadose Zone Carbon Tetrachloride Plume

Recently the Pacific Northwest National Laboratory (PNNL) used the Site-wide groundwater model to simulate fate and transport of carbon tetrachloride in the aquifer. The Groundwater/Vadose Zone Integration Project has used the System Assessment Capability to model the flux of carbon tetrachloride to the groundwater with subsequent transport in the aquifer. These results are still preliminary and have not been published. Other models, such as Subsurface Transport Over Multiple Phases (STOMP) (PNNL 2000), are available for vadose zone fate and transport modeling but have not yet been adapted to address the multi-phase aspects of the carbon tetrachloride problem.

Models should have the capability to simulate multi-phase reactive transport; include three-dimensional distribution of physical, chemical, and hydraulic properties; and include complex contaminant partitioning relations. A modeling capability is also needed that is able to estimate contaminant flux across the capillary fringe. Models for groundwater should be capable of simulating reactive transport and should include three-dimensional distributions of physical, chemical, and hydraulic properties at a scale appropriate to addressing the plume. The ability to estimate the penetration of DNAPL into the aquifer is also needed. Models applied to the carbon tetrachloride plume need to be calibrated to the specific site and plume characteristics. Collectively, the existing models have many of these capabilities, but additional effort is needed to link all of the necessary components into a package that is acceptable to the decision makers.

Table 3-4 typically presents details on the computational methods identified in Table 3-3. These details include the source and/or author of the computational method and information on how the method could be applied to this study. However, because this information is provided in the discussion above, Table 3-4 will not be used. Modeling may be used to focus characterization efforts as shown in Figure 1-4.

Table 3-4. Details on Identified Computational Methods.

DS #	Computational Method	Source/ Author	Application to Study
2 and 3	Transport model to predict groundwater impacts from vadose zone releases	Refer to discussion above.	Determination that there is a continuing source of carbon tetrachloride to groundwater that results in concentrations that exceed the MCL.

MCL = maximum contaminant level

As discussed in the modeling discussion, none of the models currently available are configured to predict the dispersed vadose zone carbon tetrachloride plume impacts on groundwater in the 200 West Area. However, the consensus of modelers consulted for this project was that the STOMP model (with further development) could possibly support the project's needs.

Step 3 – Identify the Inputs to the Decision

Therefore, the input parameters for the STOMP model were chosen to represent the informational modeling needs of this study. The input parameters include the following:

- Bulk density
- Dissolved oil adsorption function
- Hydraulic conductivity
- Particle size distribution
- Permeability-saturation function for the aqueous phase
- Permeability-saturation function for the gas phase
- Saturation-capillary pressure function
- Total porosity.

Of these input parameters, bulk density, hydraulic conductivity, particle size distribution, and total porosity would be satisfied by soil physical properties analyses.

Table 3-5 identifies each of the survey and/or analytical methods that may be used to provide the required information needed to resolve each of the DSs. The possible limitations associated with each of these methods are also provided.

Table 3-5. Potentially Appropriate Survey and/or Analytical Methods. (3 Pages)

Media	Remediation Variable	Potentially Appropriate Survey/Analytical Method	Features/Possible Limitations
Field Screening			
Soil vapor	Vapor/total carbon tetrachloride concentrations and DNAPL	Membrane interface probe	Uses a probe similar to cone penetrometer for vapor sampling. Capable of localized heating of soil to drive out residual carbon tetrachloride from soil for subsequent vapor sampling and field analysis. Can detect DNAPL presence. Exact quantification is difficult due to matrix effects.
	Vapor sampling and analysis	Soil gas collection for analysis in B&K analyzer	Uses a GeoProbe®, cone penetrometer, or soil gas probe for extraction of vapors by pump for collection in sample bags. Vapors are analyzed in the field or in a fixed laboratory.
Soil	Detection of DNAPL in soil	Ribbon non-aqueous phase liquid sampler	Deployment may use direct-push or thin-walled casing drilling. Provides direct, continuous field screening for DNAPLs with prompt results. The ribbon dyes “bleed” where contacted by non-aqueous phase liquids, providing positive indication of their presence.
	Discrete soil sampler	Cone sipper	This is a cone penetrometer-based sampling tool that is equipped with a sample chamber, tubing, and screen section for sample collection.

Step 3 – Identify the Inputs to the Decision

Table 3-5. Potentially Appropriate Survey and/or Analytical Methods. (3 Pages)

Media	Remediation Variable	Potentially Appropriate Survey/Analytical Method	Features/Possible Limitations
	Piezo cone, soil and soil gas sampler	Cone penetrometer wire-line sampler	These cone penetrometer-based wire-line tools enable sampling without retrieval of the cone penetrometer between tools. It provides 2.5-cm (1-in.)-diameter soil samples that can be sealed and shipped for analysis. Only works in the vadose zone.
	Soil permeability	Cone permeameter	This is a cone penetrometer-based method used to obtain in situ, depth-discrete measurements of soil permeability. It measures the subsurface pressure response to injected air or water.
	Fluorescence of target compounds	Induced fluorescence	Uses ultraviolet light to induce an electronic transition to an excited state in target compounds. As it relaxes to a lower state, the compound emits light (fluorescence) that is detected. The DNAPLs do not fluoresce; however, they often contain co-constituents that do fluoresce (e.g., oils).
	Raman response of DNAPL	Raman spectroscopy	This technique uses a cone penetrometer to deliver a Raman probe to subsurface. A laser is used to probe the vibrational/rotational spectra of molecules in DNAPL. This technique is weak.
	Refraction response of fluids	Index of refraction	A cone penetrometer-based technique that uses the difference in index of refraction between the pore fluids (i.e., water, gas, and non-aqueous phase liquid) to detect non-aqueous phase liquid. Heterogeneous subsurface conditions create noise.
	Microscopic conditions	Video microscope	A cone penetrometer-delivered video microscope provides a high-resolution (100 micron) color video of the subsurface materials. The DNAPLs are difficult to distinguish unless they are colored in some way.
Vapor	Evaporating carbon tetrachloride vapors	Flux chamber	Flux chambers are set on the soil surface and passively accumulate vapors for later analysis. Can be used to locate subsurface target gases or vapors.

Table 3-5. Potentially Appropriate Survey and/or Analytical Methods. (3 Pages)

Media	Remediation Variable	Potentially Appropriate Survey/Analytical Method	Features/Possible Limitations
<i>Laboratory Samples</i>			
Vapor and soil	Vapor/total carbon tetrachloride concentrations	Laboratory analysis	Highly contaminated samples require use of onsite laboratories, with associated impacts (e.g., high cost, reduced analyte lists, matrix effects, degraded detection limits, and long turnaround times). Lower contamination levels allow use of offsite laboratories, thus avoiding these limitations.

GeoProbe® is a registered trademark of GeoProbe Systems, Salinas, Kansas.

B&K = Brüel and Kjær

3.4 ANALYTICAL PERFORMANCE REQUIREMENTS

Table 3-6 defines the analytical performance requirements for the data that need to be collected to resolve each of the DSs. These performance requirements include the PQL and the precision and accuracy requirements for each of the COCs.

The analytical techniques identified in Table 3-6 fall into two categories. The analyses used in standard fixed laboratories generally require the collection of soil samples. The field screening techniques generally apply to vapor samples. The use of specific analytical techniques depends mainly on the media being sampled.

Table 3-6. Analytical Performance Requirements. (4 Pages)

COCs	CAS #	Preliminary Action Level ^a			Name/Analytical Technology	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Method B ^b (mg/kg)	Method C ^c Industrial (mg/kg)	GW Protection ^d (mg/kg)		Water ^e Low Conc. (mg/L)	Water ^e High Conc. (mg/L)	Soil-Other Low Conc. (mg/kg)	Soil-Other High Conc. (mg/kg)				
Radionuclides													
Pu-238	13981-16-3	N/A	N/A	N/A	Plutonium isotopic – AEA	1 pCi/L	130 pCi/L	1 pCi/g	1,300 pCi/g	±20%	80-120%	±35%	65-135%
Pu-239/240	Pu-239/240	N/A	N/A	N/A	Plutonium isotopic – AEA	1 pCi/L	130 pCi/L	1 pCi/g	1,300 pCi/g	±20%	80-120%	±35%	65-135%
Inorganics													
Fluoride	16984-48-8	N/A	N/A	N/A	Anions – 9056 – IC	0.5	5	5	5	r	r	r	r
Nitrate/ nitrite	NO ₃ /NO ₂ -N	N/A	N/A	N/A	NO ₃ /NO ₂ – 350.N ^f	0.075	5	0.75	10	r	r	r	r
Phosphate	14265-44-2	N/A	N/A	N/A	Anions – 9056 – IC	0.5	15	5	40	r	r	r	r
Organics													
Carbon tetrachloride	56-23-5	N/A	N/A	N/A	Volatile organics – 8260 – GCMS	0.005	0.005	0.005	0.005	r	r	r	r
DBP	107-66-4	N/A	N/A	N/A	Semi-volatiles – 8270 – GCMS as TIC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DBBP	78-46-6	N/A	N/A	N/A	Semi-volatiles – 8270 – GCMS as TIC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	67-66-3	N/A	N/A	N/A	Volatile organics – 8260 – GCMS	0.005	0.005	0.005	0.005	r	r	r	r
Methylene chloride	75-09-2	N/A	N/A	N/A	Volatile organics – 8260 – GCMS	0.005	0.005	0.005	0.005	r	r	r	r

Table 3-6. Analytical Performance Requirements. (4 Pages)

COCs	CAS #	Preliminary Action Level ^a			Name/Analytical Technology	Target Required Quantitation Limits				Precision Water	Accuracy Water	Precision Soil	Accuracy Soil
		Method B ^b (mg/kg)	Method C ^c Industrial (mg/kg)	GW Protection ^d (mg/kg)		Water ^e Low Conc. (mg/L)	Water ^e High Conc. (mg/L)	Soil-Other Low Conc. (mg/kg)	Soil-Other High Conc. (mg/kg)				
Methyl chloride	74-87-3	N/A	N/A	N/A	Volatile organics – 8260 – GCMS	0.005	0.005	0.005	0.005	r	r	r	r
Methane	74-82-8	N/A	N/A	N/A	Light gas – ASTM D1742	0.5%				r	r	r	r
MBP	1623-15-0	N/A	N/A	N/A	Semi-volatiles – 8270 – GCMS as TIC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tributyl phosphate	126-73-8	None	None	None	Semi-volatiles – 8270 – GCMS	0.1	0.5	3.3	5	r	r	r	r
COCs	CAS #	Preliminary Action Level ^a			Name/Analytical Technology	Target Required Quantitation Limits		Precision Water	Accuracy Water	Precision Vapor	Accuracy Vapor		
		Method B ^b (mg/kg)	Method C ^c Industrial (mg/kg)	GW Protection ^d (mg/kg)		Water	Vapor						
Field Screening Measurements													
Carbon tetrachloride	N/A	N/A	N/A	N/A	Membrane interface probe	0.1		0.1		N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Ribbon non-aqueous phase liquid sampler	Visual observation of DNAPL stains		Visual observation of DNAPL stains		N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Cone sipper	TBD		TBD		N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Cone penetrometer wire-line sampler	TBD		TBD		N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Cone permeameter	TBD		TBD		N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Induced fluorescence	TBD		TBD		N/A	N/A	N/A	N/A

Table 3-6. Analytical Performance Requirements. (4 Pages)

COCs	CAS #	Preliminary Action Level ^a			Name/Analytical Technology	Target Required Quantitation Limits		Precision Water	Accuracy Water	Precision Vapor	Accuracy Vapor
		Method B ^b (mg/kg)	Method C ^c Industrial (mg/kg)	GW Protection ^d (mg/kg)		Water	Vapor				
Carbon tetrachloride	N/A	N/A	N/A	N/A	Raman spectroscopy	TBD	TBD	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Index of refraction	TBD	TBD	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Video microscope	N/A	10 microns	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	B&K analyzer	TBD	1 ppmv	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	OVM	N/A	10 ppmv	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	Flux chamber	N/A	TBD	N/A	N/A	N/A	N/A
Chloroform	N/A	N/A	N/A	N/A	B&K analyzer	N/A	TBD	N/A	N/A	N/A	N/A
COCs	CAS #	Preliminary Action Level ^a			Name/Analytical Technology	Target Required Quantitation Limits	Precision Vapor	Accuracy Vapor			
		Method B ^b (mg/kg)	Method C ^c Industrial (mg/kg)	GW Protection ^d (mg/kg)							
Physical Properties											
Bulk density	N/A	N/A	N/A	N/A	D2937	--	N/A	N/A			
Dissolved oil adsorption function	N/A	N/A	N/A	N/A	--	--	N/A	N/A			
Hydraulic conductivity	N/A	N/A	N/A	N/A	--	--	N/A	N/A			
Particle size distribution	N/A	N/A	N/A	N/A	D2216	wt%	N/A	N/A			
Permeability-saturation function for the aqueous phase	N/A	N/A	N/A	N/A	--	--	N/A	N/A			

Table 3-6. Analytical Performance Requirements. (4 Pages)

COCs	CAS #	Preliminary Action Level ^a			Name/Analytical Technology	Target Required Quantitation Limits	Precision Vapor	Accuracy Vapor
		Method B ^b (mg/kg)	Method C ^c Industrial (mg/kg)	GW Protection ^d (mg/kg)				
Permeability-saturation function for the gas phase	N/A	N/A	N/A	N/A	--	--	N/A	N/A
Saturation-capillary pressure function	N/A	N/A	N/A	N/A	--	--	N/A	N/A
Total porosity	N/A	N/A	N/A	N/A	--	--	N/A	N/A

^a The preliminary action levels are not applicable for this study (as noted in Table 1-6).

^b MTCA Method B soil values for direct exposure.

^c MTCA Method C industrial soil values for direct exposure.

^d MTCA Method B soil values for groundwater protection.

^e Water values for sampling quality control (e.g., equipment blanks/rinses) or drainable liquid (if recovered).

^f As required by corresponding EPA's SW-846 method (EPA 1997), as implemented through the *Hanford Analytical Services Quality Assurance Requirements Document* specifications (DOE-RL 1998).

AEA = alpha energy analysis

ASTM = American Society for Testing and Materials

CAS = Chemical Abstract Services

GCMS = gas chromatograph/mass spectrometry

GW = groundwater

IC = ion chromatography

MTCA = *Model Toxics Control Act* (Washington Administrative Code [WAC] 173-340)

N/A = not applicable

OVM = organic vapor monitor

TBD = to be determined

TIC = tentatively identified compound

4.0 STEP 4 – DEFINE THE BOUNDARIES OF THE STUDY

4.1 OBJECTIVE

In Step 4, the DQO team identifies the spatial, temporal, and practical constraints on the sampling design and considers the consequences. This objective (in terms of the spatial, temporal, and practical constraints) ensures that the sampling design results in the collection of data that accurately reflect the true condition of the site and/or populations being studied.

DQO Step 4 is a critical aspect of groundwater and vapor plume DQO studies, as it focuses attention on the areas of significance from a decision-making standpoint. Spatial decision units will be established with application priorities that lead directly to the development of the sampling design in DQO Step 7.

4.2 DEFINE THE BOUNDARIES OF THE STUDY

Table 4-1 defines the population of interest to clarify what the samples are intended to represent. The characteristics that define the population of interest are also identified.

Table 4-1. Characteristics that Define the Population of Interest.

DS #	Population of Interest	Characteristics
1, 2, and 3	The set of carbon tetrachloride-contaminated samples in the vadose zone under the 200 West Area.	Vapor, total concentrations, and/or free liquid accumulations of carbon tetrachloride in soil samples.

Table 4-2 defines the spatial boundaries of the decision and the domain or geographic area (or volume) within which all decisions must apply (in some cases, this may be defined by the OU). The domain is a region distinctly marked by some physical features (i.e., volume, length, width, and boundary).

Table 4-2. Geographic Boundaries of the Investigation.

DS #	Geographic Boundaries of the Investigation
1, 2, and 3	The geographic boundary for the investigation is the perimeter defined by 20 th Street, Camden Avenue, 16 th Avenue, and Dayton Avenue in the 200 West Area, from the ground surface to the groundwater.

In this part of DQO Step 4, the population is divided into strata that have homogeneous characteristics. The ultimate goal is to define the decision units important to the sampling

Step 4 – Define the Boundaries of the Study

BHI-01544

Rev. 0

design. The DQO team must evaluate process knowledge, historical data, and plant configurations to establish the logic that supports alignment of the population into strata and decision units.

The strata are shown in Table 4-3, leading to the development of the spatial decision units.

Table 4-3. Strata with Homogeneous Characteristics.

DS #	Population of Interest	Strata	Homogeneous Characteristic Logic
1, 2, and 3	The set of carbon tetrachloride-contaminated samples within the vadose zone under the 200 West Area.	Shallow vadose zone (ground surface to approximately 15.3 m [50 ft] below grade)	The portion of the vadose zone that received releases of aqueous and free liquid carbon tetrachloride during plant operations. The shallow vadose zone is normally accessible for relatively simple and inexpensive vapor sampling activities.
		Intermediate vadose zone (approximately 15.3 m [50 ft] below grade to approximately 15.3 m [50 ft] below Plio-Pleistocene)	This region is important to verify carbon tetrachloride accumulations that have potential for current or future groundwater impacts. Because of its depth within the vadose zone, access for sampling requires more expensive intrusive methods than the shallow vadose zone.
		Deep vadose zone (approximately 15.3 m [50 ft] below Plio-Pleistocene to the groundwater table)	This region normally requires expensive drilling methods for characterization. It is the critical region for detection of active carbon tetrachloride sources to groundwater.

The temporal boundaries of the decision are defined in Table 4-4.

Table 4-4. Temporal Boundaries of the Investigation.

DS #	Timeframe	When to Collect Data
1, 2, and 3	Collect samples during periods of low barometric pressure	The upper 0.9 m (3-ft) of the vadose zone is extremely sensitive to barometric pressure changes that could affect shallow soil gas sampling results. Therefore, shallow soil gas sampling should be performed below that depth, particularly during declining high barometric pressures. Summer months typically exhibit fairly stable barometric pressures and may not be ideal for that type of sampling.

Step 4 – Define the Boundaries of the Study

4.3 SCALE OF DECISION MAKING

Table 4-5 defines the scale of decision making for each DS. The scale of decision making is defined as the smallest, most appropriate subsets of the population (subpopulation) for which decisions will be made based on the spatial or temporal boundaries of the area under investigation.

Table 4-5. Scale of Decision Making.

DS #	Population of Interest	Geographic Boundary	Temporal Boundary		Decision Units
			Time-frame	When to Collect Data	
1, 2, and 3	The set of carbon tetrachloride-contaminated samples in the vadose zone under the 200 West Area.	The geographic boundary for the investigation is the perimeter defined by 20th Street, Camden Avenue 16 th Avenue, and Dayton Avenue in the 200 West Area, from the ground surface to groundwater.	Collect samples during periods of declining barometric pressure.	The upper 0.9 m (3 ft) of the vadose zone is extremely sensitive to barometric pressure changes that could affect shallow soil gas sampling results. Therefore, shallow soil gas sampling should be performed below that depth, particularly during declining high barometric pressures. Summer months typically exhibit fairly stable barometric pressures and may not be ideal for that type of sampling.	Shallow vadose zone
					Intermediate vadose zone
					Deep vadose zone

4.4 PRACTICAL CONSTRAINTS

Table 4-6 identifies all of the practical constraints that may impact the data collection effort. These constraints include physical barriers, difficult sample matrices, high radiation areas, or any other condition that will need to be taken into consideration in the design and scheduling of the sampling program.

Table 4-6. Practical Constraints on Data Collection.

- Significant contamination concentrations are present in the 200-PW-1 OU waste sites. Sampling performed within the boundaries of those sites will require the use of contamination controls that limit and hinder drilling and sample collection operations.
- Borehole soil sampling equipment may not obtain sufficient volumes of sample media if the sampled zone is 0.6 m (2 ft) thick or less. Advancement of borehole casing may drag contamination downhole. Drilling operations may volatilize the carbon tetrachloride present, and sample transfers in the field and laboratory add to the losses, generally resulting in inaccurate measurements. Therefore, vapor sampling methods are preferred for carbon tetrachloride analyses.
- Sampling by cone penetrometer may be depth-limited because of geologic features that cause refusal.
- The soils in the Plio-Pleistocene unit may include cemented zones that could pose difficulties in sample collection.
- Health and safety constraints may be imposed during characterization sampling to ensure that ALARA issues are properly addressed when sampling potentially TRU-contaminated, greater than Class C, and other radiologically contaminated soils.
- Laboratory constraints are expected when analyzing soil samples with high contaminant concentrations. Soil samples in this category would be analyzed in an onsite laboratory. Cost impacts are expected. If analytical turnaround times are extended, the short hold times may be exceeded.
- Extreme weather conditions may limit or shut down field operations.
- Shallow soil gas sampling should be performed during declining high barometric pressures. Summer months typically exhibit fairly stable barometric pressures and may not be ideal for that type of sampling.
- Access to burial grounds and liquid waste discharge sites may be limited by worker protection requirements or radiological or other constraints.

ALARA = as low as reasonably achievable

TRU = waste materials contaminated with 100 nCi/g of transuranic materials having half-lives longer than 20 years

5.0 STEP 5 – DEVELOP A DECISION RULE

The purpose of DQO Step 5 is initially to define the statistical parameter of interest (i.e., maximum, mean, or 95% upper confidence level [UCL]) that will be used for comparison against the action level. The statistical parameter of interest specifies the characteristic or attribute that a decision maker would like to know about the population. The preliminary action level for each of the COCs is also identified in DQO Step 5. When this is established, a decision rule (DR) is developed for each DS in the form of an “IF...THEN...” statement that incorporates the parameter of interest, the scale of decision making, the preliminary action level, and the AAs that would result from resolution of the decision. Note that the scale of decision making and AAs were identified earlier in DQO Steps 4 and 2, respectively.

5.1 INPUTS NEEDED TO DEVELOP DECISION RULES

Tables 5-1, 5-2, and 5-3 present the information needed to formulate the DRs in Section 5.2. This information includes the DSs and AAs identified in DQO Step 2, the scale of decision making identified in DQO Step 4, and the statistical parameters of interest and preliminary action levels for each of the COCs.

Table 5-1. Decision Statements.

DS #	Decision Statement
1	Determine where the known or suspect carbon tetrachloride release sites to groundwater are located in the vadose zone and evaluate for current impacts to groundwater, evaluate for potential future impacts to groundwater, or do not evaluate for current or future impacts.
2	Determine if known or suspect carbon tetrachloride release sites in the vadose zone are currently impacting groundwater and evaluate expansion of the vapor extraction system to enhance the expedited response action, or evaluate remedial alternatives in a FS.
3	Determine if known or suspect carbon tetrachloride release sites within the vadose zone have the potential to impact groundwater in the future and evaluate expansion the vapor extraction system to enhance the expedited response action, or evaluate remedial alternatives in a FS.

Step 5 – Develop a Decision Rule

Table 5-2. Inputs Needed to Develop Decision Rules.

DS #	COCs	Parameter of Interest	Scale of Decision Making	Action Levels
1, 2, and 3	Carbon tetrachloride vapors ^a	Detected values	Shallow vadose zone	Values determined by modeling and/or engineering judgment
			Intermediate vadose zone	
			Deep vadose zone	

^a As noted in Table 4-6, soil sampling for detection of carbon tetrachloride is not considered suitable because of vaporization losses. Therefore, soil samples will not be analyzed for totals concentrations or free liquids, and vapor sampling and analysis will be performed instead.

5.2 DECISION RULES

The output of DQO Step 5 and the previous DQO steps are combined into “IF...THEN” DRs that incorporate the parameter of interest, the scale of decision making, the action level, and the actions that would result from resolution of the decision. The DRs are listed in Table 5-3.

Table 5-3. Decision Rules.

DR #	Decision Rule
1	If the detected carbon tetrachloride concentrations at known or suspect release site locations within the shallow vadose zone, the intermediate vadose zone, or the deep vadose zone are equal to or greater than the values determined by modeling and/or engineering judgment as representing a source location, then evaluate for current impacts to groundwater, evaluate for potential future impacts to groundwater, or do not evaluate for current or future impacts.
2	If the detected carbon tetrachloride vapor concentrations at known or suspect release site locations within the shallow vadose zone, the intermediate vadose zone, or the deep vadose zone are equal to or greater than the values determined by modeling and/or engineering judgment as currently impacting groundwater, then evaluate expansion of the vapor extraction system to enhance the expedited response action, or evaluate remedial alternatives in a FS.
3	If the detected carbon tetrachloride vapor concentrations at known or suspect release site locations within the shallow vadose zone, the intermediate vadose zone, or the deep vadose zone are equal to or greater than the values determined by modeling and/or engineering judgment as having potential to impact groundwater in the future, then evaluate expansion of the vapor extraction system to enhance the expedited response action, or evaluate remedial alternatives in a FS.

6.0 STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

Because analytical data can only estimate the true condition of the site under investigation, decisions that are made based on measurement data could potentially be in error (i.e., decision error). For this reason, the primary objective of DQO Step 6 is to determine which DSs (if any) requires a statistically based sample design. For those DSs requiring a statistically based sample design, DQO Step 6 defines tolerable limits on the probability of making a decision error.

This project faces unique characterization challenges because of the 73.2-m (240-ft)-thick vadose zone that covers large land areas. There are potentially significant impediments to direct-push technologies at depth and extreme costs for borehole sampling if a statistically based sampling design is applied. In view of these financial and practical constraints, a statistical sampling approach would not be an appropriate choice. Consequently, the methods normally used to quantify uncertainty cannot be used to probabilistically determine decision errors. Therefore a non-statistical (judgmental) sampling design has been chosen to establish the sampling frequencies and to focus data acquisition in locations that support the decision-making needs.

It is noted that a significant groundwater-monitoring network exists within the 200 West Area, which will provide ultimate verification of the effectiveness of the remedial decision making.

6.1 UNCERTAINTY DISCUSSION

Because a judgmental sampling design has been selected, uncertainty is evaluated for each of the decisions in this study. The object of this study is to characterize the vadose zone for carbon tetrachloride sources affecting the groundwater. Within the study area, most if not all of the carbon tetrachloride release modes have been identified (see Figure 1-5, which shows the seven potential release modes). The concentrations of carbon tetrachloride vapors within the release site areas are expected to be high relative to the ultimate action levels. The available analytical methods are not likely to yield false-negative or false-positive values based on the ranges of values expected near release site locations. Therefore, the ability to locate release sites with the available analytical methods is considered adequate to answer the study questions with a reasonable degree of confidence.

Data gaps that exist in the waste disposal records from 1949 until approximately 1988 adversely affect decision-making uncertainty (due to the potential presence of undocumented releases). In addition, uncertainty may increase with the depth in this study, because contaminant concentrations in the soil may decrease with increasing distance from the point of origin. A qualitative ranking of uncertainty for the decisions in this study is provided in Table 6-1.

Step 6 – Specify Tolerable Limits on Decision Errors

BHI-01544

Rev. 0

Table 6-1. Relative Uncertainty Ranking for Study Decisions.

DS #	Decision	Relative Uncertainty Ranking – Explanation
1	Location of known or suspect carbon tetrachloride release sites	<u>Low</u> – Concentrations sufficient to identify the sources as potentially impacting groundwater must be above decision-making thresholds, which would minimize the probability of making decision errors.
2	Release sites that are currently impacting groundwater	<u>Low to moderate</u> – Concentrations may decrease with distance from the release, increasing uncertainty.
3	Release sites with potential to impact groundwater in the future	<u>Highest</u> – Release sites that are not currently impacting groundwater may have lower concentrations in the shallow vadose zone in comparison with sources known to be currently impacting groundwater, and may be difficult to characterize in the deep vadose zone.

7.0 STEP 7 – OPTIMIZE THE DESIGN

7.1 PURPOSE

The purpose of DQO Step 7 is to identify the most resource-effective design for generating data to support decisions while maintaining the desired degree of precision and accuracy. When determining an optimal design, the following activities should be performed:

- Review the DQO outputs from the previous DQO steps and the existing environmental data.
- Develop general data collection design alternatives.
- Select the sampling design (e.g., techniques, locations, or numbers/volumes) that most cost effectively satisfies the project's goals.
- Document the operational details and theoretical assumptions of the selected design.

7.2 OPTIMIZE THE DESIGN

Table 7-1 identifies information in relation to determining the data collection design.

Table 7-1. Determine Data Collection Design.

DS #	Statistical	Non-Statistical	Rationale
1 and 2	N/A	Non-statistical sampling design	Judgmental data collection design is applicable to the investigation because of the high costs associated with sampling in the deep vadose zone and because sampling must be focused in specific areas of concern.

N/A = not applicable

Table 7-2 is used to develop general data collection design alternatives. If the data collection design for a given decision will be non-statistical, determine what type of non-statistical design is appropriate (i.e., haphazard or judgmental).

Table 7-2. Determine Non-Statistical Sampling Design.

DR #	Haphazard	Judgmental
1, 2, and 3	None	Professional judgmental sampling design is indicated.

The field screening data collection alternatives for this project are described in Table 7-3.

Table 7-3. Potential Field Screening Alternatives.

Media	Screening Technology	Potential Implementation Design	Limitations
In situ DNAPL detection	Ribbon non-aqueous phase liquid sampler	Detection of DNAPLs beneath release site locations	To justify use, suspect DNAPL locations must be identified.
	Membrane interface probe		
	Induced fluorescence		
	Raman spectroscopy		
	Index of refraction		
	Video microscope		
In situ vapor measurements	Flux chamber	Systematic grid sampling for detection of vapors within surface soils	Requires installation and removal from the top 45.7 cm (18 in.) of surface soils (labor and excavation permit).
Vapor	Cone penetrometer wire-line sampler	Systematic or focused deployment of cone penetrometers	Requires access for installation of cone penetrometer tubes. Installation is limited to vertical orientation. Depth of vertical extent may also be limited.
Vapor/totals concentration	Membrane interface probe		
Vapor	Soil gas collection for analysis in B&K analyzer	Systematic or focused deployment of cone penetrometers or soil gas sampling probes	
Vapor	Vapor sampling by OVM	Soil vapor sampling for borehole vapor sampling decision making	Requires installation of borehole packers for vapor sampling through teflon tubing at the bottom of the borehole.

The design options are evaluated based on cost and ability to meet the DQO constraints. The results of the trade-off analyses should lead to one of two outcomes: (1) the selection of a design that most efficiently meets all of the DQO constraints, or (2) the modification of one or more outputs from DQO Steps 1 through 6 and the selection of a design that meets the new constraints.

The key features of the selected design are then documented, including (for example) the following:

- Descriptions of sample locations, strata, inaccessible areas, and maps (if beneficial)
- Directions for selecting sample locations (if the selection is not necessary or appropriate at this time)

Step 7 – Optimize the Design

- Order in which samples should be collected (if important)
- Stopping rules (if applicable)
- Special sample collection methods
- Special analytical methods.

7.3 SAMPLING OBJECTIVES

In Table 3-2 it was concluded that the historical characterization data available for the 200-PW-1 OU dispersed carbon tetrachloride plume satisfy the data quality needs, but that additional data area required for the decisions being made. Therefore, additional characterization is desired. The characterization objectives identified in Section 1.3 result in the characterization goals shown in Table 7-4.

Table 7-4. Characterization Goals and Drivers.

Characterization Goals	Waste Site	Sampling Area	Driver
Determine the carbon tetrachloride vapor concentrations with depth at selected locations	Dispersed carbon tetrachloride plume in 200 West Area	Vadose zone at release site locations	RI/FS decision making
Obtain soil physical properties data		Vadose zone at release site locations	Vadose zone contaminant transport modeling input parameters

7.4 NON-STATISTICAL IMPLEMENTATION DESIGN

The decisions in this DQO effort address locating and characterizing the sources of carbon tetrachloride contamination that are presently impacting groundwater, as well as the known and suspect release sites with potential to impact groundwater in the future. Because of the significant expense associated with exploratory characterization efforts in radioactively contaminated areas, resources must be focused in areas with the highest potential for detecting the active sources. Therefore, a two-step sampling design was developed that considers the uncertainty rankings developed in Table 6-1. In Step I, this approach targets the known and suspect release sites in the shallow and intermediate vadose zone, an activity expected to have the lowest degree of uncertainty and the lowest costs. In Step II, the sampling design shifts to the deep vadose zone, which has a higher degree of uncertainty but has available environmental data that enhance the conceptual contaminant distribution model(s). This approach minimizes the potential for expensive sampling errors in deep vadose zone investigations.

The two steps in this sampling approach can be summarized as follows:

- **Step I** – Within the area of this study, characterize the suspect release sites in the shallow and intermediate vadose zone from the ground surface to the Plio-Pleistocene formation (to the extent practicable) using vapor sampling techniques. The purpose is to determine the locations of carbon tetrachloride release sites for further investigation in Step II.
- **Step II** – Based on Step I data, select locations for intrusive borehole sampling to the groundwater. The purpose is to detect carbon tetrachloride accumulations that are currently impacting or may impact groundwater in the future. Soil samples will also include physical properties analyses to support vadose zone transport modeling.

Figure 7-1 provides an illustration of the relationships between the characterization stages, the vadose zone decision units, and the relative uncertainty rankings.

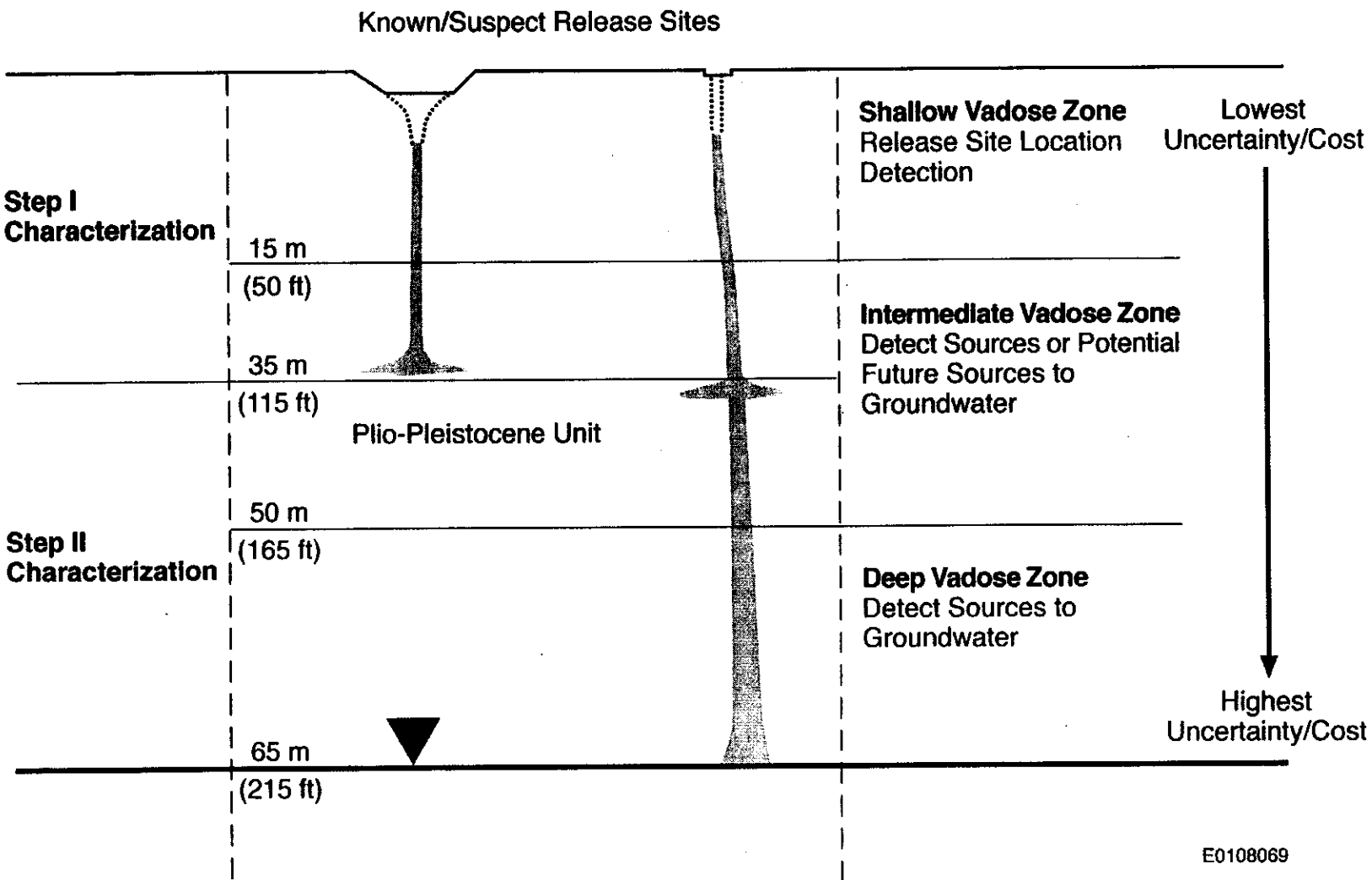
7.4.1 Step I Characterization

As discussed in Section 1.6 and as shown in Figure 1-5, seven carbon tetrachloride release modes have been identified as having potential to impact groundwater in this study. The correlation between potential release modes and elements of the sampling design is provided in Table 7-5.

In addition to the field activities described in this DQO summary report, data integration and numerical modeling will be conducted to support refinement of the preliminary conceptual contaminant distribution model. Specific tasks include the following:

- Data collected by other projects (e.g., well drilling within the PFP protected area and well deepening near the 216-Z-9 Trench) will be used to augment the existing 200 Area carbon tetrachloride database.
- Historical research/data gathering of process knowledge regarding waste disposal practices in the LLWMA #4 and LLWMA #3 burial grounds.
- In support of the field investigations, the hydraulic flow fields during and after carbon tetrachloride disposal to known waste sites will be evaluated to determine if the distribution of carbon tetrachloride in the groundwater is reasonable based on hydraulics alone. Results of this evaluation may identify additional contributing carbon tetrachloride disposal areas.

Figure 7-1. Characterization Stage, Decision Unit, and Relative Uncertainty Relationships.



E0108069

Table 7-5. Sampling Design to Investigate Potential Carbon Tetrachloride Release Modes.

Potential Release Mode	Step I Sampling Design (Table 7-6)
Carbon tetrachloride drum storage releases	<i>PFP facility area (drum storage releases, PFP process releases, PFP piping and drain leaks, liquid discharge pipeline leaks, liquid waste discharges)</i> Shallow soil vapor sampling using a systematic grid within the PFP facility area. Deeper soil vapor sampling at shallow concentration hot spots and at known drum storage area.
Z Plant complex process releases	
Z Plant complex piping and drain leaks	
Discharge pipeline leaks	
Deliberate discharges to engineered liquid waste sites	
Z Plant complex HVAC releases	<i>PFP HVAC condensate waste sites</i> Soil vapor sampling at selected locations at the french drains, ponds, and ditches that received HVAC condensate.
Discharge pipeline leaks	<i>Soils adjacent to liquid discharge pipelines</i> Soil vapor sampling at pre-determined spacing adjacent to pipeline pathways outside of the PFP facility area.
Deliberate discharges to engineered liquid waste sites	<i>Liquid waste discharge sites</i> Soil vapor sampling at selected locations at liquid waste discharge sites that received carbon tetrachloride wastes.
Burial ground releases from carbon tetrachloride-containing wastes	<i>Burial grounds</i> Vapor sampling at burial ground vent risers. Deeper soil vapor sampling adjacent to burial ground trenches, including near vapor hot spots identified by vent riser sampling.

- Numerical modeling of carbon tetrachloride flow and transport in the vadose zone will be conducted to help guide field investigations of the dispersed plume. Although the modeling effort may not be completed in time to support Step I sampling, it is anticipated that the predictions of the distribution of carbon tetrachloride in the vadose zone and its potential for continued migration to groundwater will aid in formulating Step II sampling plans.
- Visualization of the Step I sampling results in three dimensions and geostatistical analysis of the data may be considered during data evaluation. Geostatistical analysis would include mapping of probability levels (i.e., the probability that the concentration exceeds a specified value such as a regulatory level) and mapping of uncertainty (e.g., mapping the variance of the concentration to identify areas that have the greatest uncertainty about the concentration).

The main components of the Step I sampling design include the following:

- Extensive use of a direct-push technology (e.g., cone penetrometer or GeoProbe) for vapor sampling in suspect release site locations to determine vadose zone vapor concentrations. The acquired data will be used to enhance the conceptual contaminant distribution model(s),

Step 7 – Optimize the Design

thereby supporting Step II characterization decisions. Suspect release sites that offer direct access for installation of this type of technology include the PFP drum storage area; the 216-Z-13, 216-Z-14, and 216-Z-15 french drains; the 216-Z ditches; and the liquid waste discharge pipelines from the PFP, as well as the liquid waste discharge sites, settling tanks, and unplanned release sites. The direct-push technology sampling locations and specific sampling depths are presented in Table 7-6.

- Shallow soil vapor sampling within the PFP protected area (i.e., within the security fence around the PFP facility) to identify carbon tetrachloride concentration hot spots. A systematic grid was selected for sampling point identification because of the complexity and uncertainty of release modes and locations. The systematic grid for collecting new shallow soil vapor samples within the PFP protected area and the locations of previous shallow soil vapor samples are shown in Figure 7-2. The shallow soil vapor survey results will be used to evaluate near-surface release modes.
- Soil vapor sampling using a direct-push technology to investigate concentration hot spots identified during the shallow soil vapor sampling.
- Vapor sampling from vent risers in the LLWMA #4 burial grounds. Typical burial ground configurations are shown in Figure 7-3.
- Soil vapor sampling adjacent to LLWMA #4 burial ground trenches.

Because the Step I sampling design is focused entirely on vapor sampling, soil samples will not be collected for physical properties analyses (as discussed in Section 3.3.2 and Table 7-4). However, physical properties data may be obtained during the Step II field characterization, when borehole sampling is expected, and from the 200-PW-1 OU representative waste sites RI characterization.

Table 7-6. Step I Sampling Design.^a (4 Pages)

Sample Collection Methodology	Key Features of Design	Basis for Sampling Design
PFP Facility Area (Drum Storage Releases, PFP Process Releases, PFP Piping and Drain Leaks, Liquid Discharge Pipeline Leaks, Liquid Waste Discharges [241-Z-361 Settling Tank and UPR-200-W-103])		
Shallow soil vapor sampling around the PFP facility.	Shallow soil vapor sampling within the PFP protected area for identification of carbon tetrachloride hot spots. Install soil vapor probes to a depth of 1.5 m (5 ft). Use a systematic grid to identify sampling locations (Figure 7-2).	Initial subsurface screening around the PFP facility. Sampling at 1.5-m (5-ft) depth minimizes dilution caused by barometric pumping and enables this data to be compared with previous shallow soil vapor samples collected outside the PFP facility. A systematic grid was selected because of complexity and uncertainty of release modes and locations.

Step 7 – Optimize the Design

Table 7-6. Step I Sampling Design.^a (4 Pages)

Sample Collection Methodology	Key Features of Design	Basis for Sampling Design
Focused soil vapor sampling using direct-push technology.	Use direct-push technology for vapor sampling around PFP in locations where concentration hot spots were detected during shallow soil vapor sampling. At each direct-push location, sample vapors at 4.6 and 7.6 m (15 and 25 ft) bgs, if possible, to indicate vertical trend.	Focused vapor sampling will be used to investigate potential release sites around PFP, including drum storage releases, PFP process releases, PFP piping and drain leaks, liquid discharge pipeline leaks, and liquid waste discharges (241-Z-361 settling tank and UPR-200-W-103) (Figure 7-4).
	If shallow vapor sampling does not detect concentration hot spots in the drum storage area, use direct-push technology for vapor sampling within the footprint of the drum storage area at a minimum of one location (Figure 7-4). At each direct-push location, sample vapors at 4.6 and 7.6 m (15 and 25 ft) bgs, if possible, to indicate vertical trend and continue sampling in 25-ft-depth increments until refusal or until reaching approximately 38.1 m (125 ft) bgs. ^c	Focused vapor sampling will be used to investigate known carbon tetrachloride storage area with potential for release. Although the relative size of suspected area would require two locations (Table 7-7), shallow soil vapor sampling to detect concentration hot spots reduces the required number of direct-push locations to one.
PFP HVAC Condensate Waste Sites		
Soil vapor sampling using direct-push technology adjacent to the french drains (216-Z-13, 216-Z-14, and 216-Z-15), the 216-Z-21 Pond, and the combined 216-Z ditches site (216-Z-1D, 216-Z-11, 216-Z-19, and 216-Z-20 ditches).	<p>Judgmental placement of one direct-push sampling location adjacent to the footprint of each french drain (Figure 7-4).</p> <p>Judgmental placement of three locations adjacent to the 216-Z-21 Pond: one at the head-end side and two near the midpoint on the lateral sides of the site (Figure 7-5).</p> <p>Judgmental placement of three locations adjacent to the 216-Z ditches site: two near the head end and one near the midpoint (Figure 7-5).</p> <p>At each direct-push sampling location, sample vapors at the infiltration elevation at the engineered structure, at 4.6 m (15 ft) bgs (if deeper than the infiltration elevation), and 7.6 m (25 ft) bgs. Samples must be collected from a minimum of one location at each site to 7.6 m (25 ft) bgs.^b</p> <p>At each direct-push sampling location deeper than 7.6 m (25 ft) bgs, continue sampling in 7.6-m (25-ft)-depth increments until direct-push technology refusal or until reaching approximately 38.1 m (125 ft) bgs.^c</p>	Screening to determine the presence of carbon tetrachloride vapor beneath the french drains and ditches. Number of direct-push technology locations based on relative size of waste sites (Table 7-7). Sampling locations may be eliminated if sites are inaccessible. In situ soil vapor sampling during drilling of a borehole at the 216-Z-11 ditch may be used in lieu of one direct-push sampling location at the combined 216-Z ditches site.

Step 7 – Optimize the Design

Table 7-6. Step I Sampling Design.^a (4 Pages)

Sample Collection Methodology	Key Features of Design	Basis for Sampling Design
Soils Adjacent to Liquid Discharge Pipelines		
Soil vapor sampling using direct-push technology adjacent to the discharge pipelines from the PFP to the 216-Z-1A site (including 216-Z-1, 216-Z-2, and 216-Z-3), 216-Z-7, 216-Z-8, 216-Z-9, 216-Z-12, 216-Z-16, 216-Z-17, 216-Z-18, and 216-Z-21 liquid waste discharge sites, and the 216-Z ditches site (216-Z-1D, 216-Z-11, 216-Z-19, and 216-Z-20 ditches).	Starting at the PFP fence, place the direct-push technology locations on a systematic-random basis on approximately 15.3-m (50-ft) centers along discharge pipelines (Figure 7-6). Pipeline pathways within the PFP fenceline will be investigated as part of the PFP facility area investigation. At each direct-push sampling location, sample vapors at an elevation that corresponds to the bottom of the discharge pipeline, at 4.6 m (15 ft) bgs (if deeper than pipeline), and 7.6 m (25 ft) bgs. Samples must be collected from a minimum of one location at each discharge pipeline at 7.6 m (25 ft) bgs. ^b	Subsurface screening method used to determine the presence of carbon tetrachloride vapor near and beneath the discharge pipelines. Sampling locations may be eliminated if pipeline pathways are inaccessible or if existing soil vapor probes are nearby (within 15.3 m [50 ft]) and available for sampling.
	For all but the 216-Z-1A and 216-Z-9 discharge pipelines, defer vapor sampling until after evaluating vapor sampling results from the corresponding liquid waste discharge sites.	If carbon tetrachloride vapor is not detected in the liquid waste discharge sites, eliminate vapor sampling at the corresponding discharge pipelines.
Liquid Waste Discharge Sites		
Soil vapor sampling using direct-push technology adjacent to the 216-T-19, 216-Z-1A (including 216-Z-1, 216-Z-2, and 216-Z-3), 216-Z-7, 216-Z-8, 216-Z-9, 216-Z-12, 216-Z-16, 216-Z-17, and 216-Z-18 liquid waste discharge sites.	Judgmental placement of direct-push technology locations adjacent to each liquid waste discharge site for vapor sampling in accordance with Table 7-7. At all sites, one sampling location should be located on the head-end side of the site. A second location would be located at midpoint on one lateral side of the site. A third location would be located on the distal side of the site. Liquid discharge sites within the PFP fenceline will be investigated as part of the PFP Facility Area investigation. At each direct-push sampling location, sample vapors at the infiltration elevation at the engineered structure, at 4.6 m (15 ft) bgs (if deeper than the infiltration elevation), and 7.6 m (25 ft) bgs. Samples must be collected from a minimum of one location at each engineered structure to 7.6 m (25 ft) bgs. ^b At each direct-push sampling location deeper than 7.6 m (25 ft) bgs, continue sampling in 7.6-m (25-ft)-depth increments until refusal or until reaching approximately 38.1 m (125 ft) bgs. ^c	Subsurface screening method used to determine the presence of carbon tetrachloride vapor beneath the known/suspect release sites. At the 216-Z-9 site, permanent probes may need to be installed at target depths deeper than 15.3 m (25 ft) bgs. These probes would be sampled during the fourth quarter of FY02 following conclusion of FY02 soil vapor extraction operations at that location.

Table 7-6. Step I Sampling Design.^a (4 Pages)

Sample Collection Methodology	Key Features of Design	Basis for Sampling Design
Burial Grounds		
Vapor sampling from vent risers in LLWMA #4 burial grounds.	Sample vapors from vent risers aligned with the center of the burial ground trench. Minimum sample spacing is 15.3 m (50 ft).	Vent risers offer a simple and inexpensive means of vapor sampling in the burial grounds. Results can be used to focus deeper soil vapor sampling using direct-push technology. Sampling will focus on vent risers at LLWMA #4 from 19 th Street to west of the north side of the 216-Z-18 Crib based on the higher carbon tetrachloride groundwater concentrations underlying this area.
Focused soil vapor sampling using direct-push technology.	Sample soil vapor at a minimum of five locations adjacent to the burial ground trenches between 19 th Street and the north side of 216-Z-18 Crib (including locations off-center from any hot spots identified by vent riser sampling). At each direct-push sampling location, sample vapors at 4.6 and 7.6 m (15 and 25 ft) bgs. Samples must be collected from a minimum of one location at each focus area to 7.6 m (25 ft) bgs. ^b At each direct-push sampling location deeper than 7.6 m (25 ft) bgs, continue sampling in 7.6-m (25-ft)-depth intervals until refusal or until reaching approximately 38.1 m (125 ft) bgs. ^c	Soil vapor sampling will allow comparison of results with other waste site sampling.

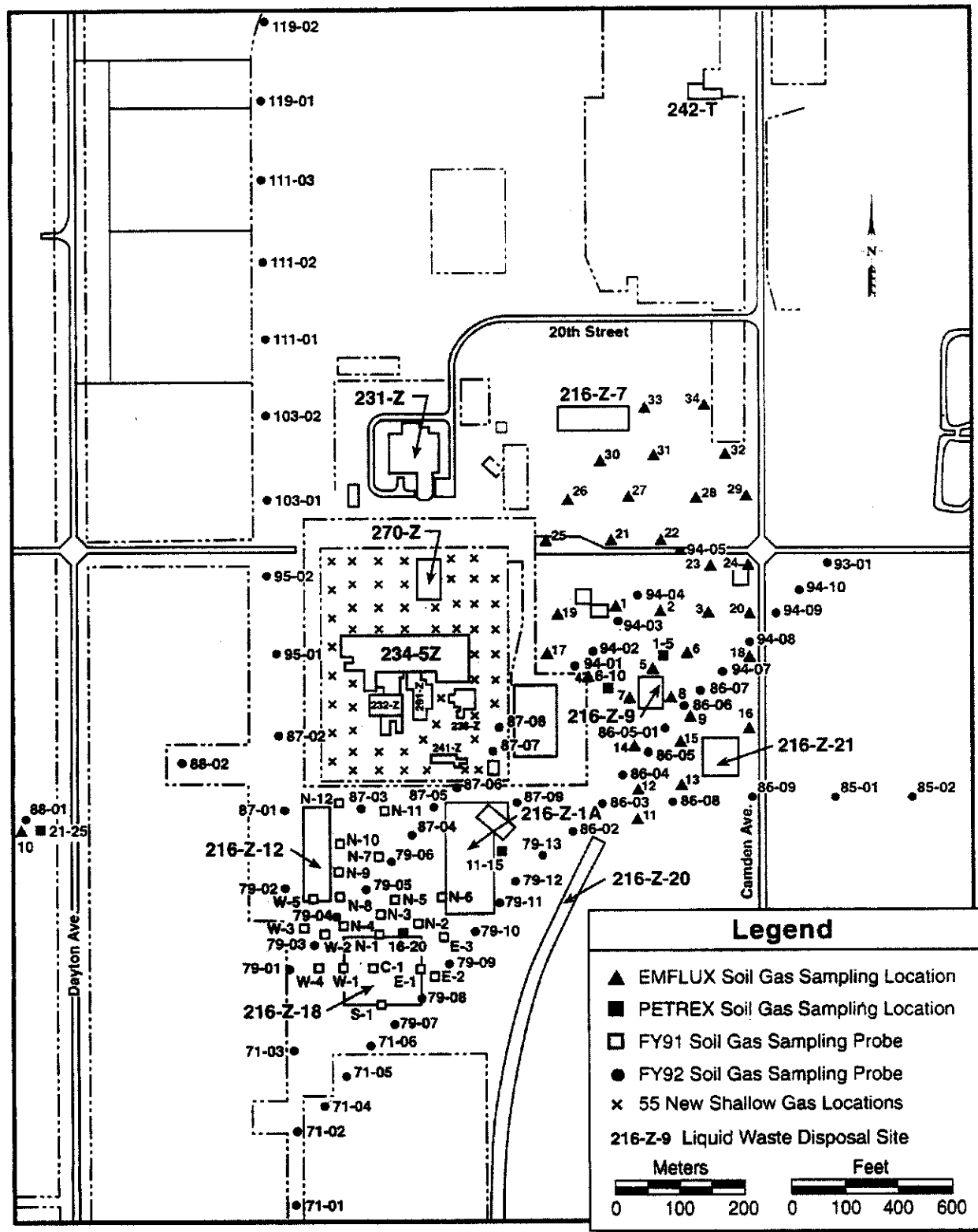
^a Step I sampling does not address all of the data gaps identified during the DQO process. See the potential sampling design limitations discussion in Section 3.2.4.

^b If necessary, up to five additional direct-push sampling locations must be installed until one reaches a depth of 7.6 m (25 ft) bgs.

^c A 7.6-m (25-ft) sampling interval was selected for sampling deeper than 7.6 m (25 ft) bgs because (1) it is anticipated that the vapor concentration gradient will not change rapidly with depth, and (2) it will allow a broader exploration of the vadose zone by limiting the number of samples required at any one location. The sandy silt layer in the Plio-Pleistocene unit is anticipated at approximately 115 ft bgs; the caliche layer in the Plio-Pleistocene unit is anticipated at approximately 38.1 m (125 ft) bgs. The direct-push installations should not extend into the caliche layer.

Soil vapor sampling using direct-push technology will generally involve one-time installation of direct-push rods and vapor sampling, followed by removal of the rods. However, in locations with elevated vapor concentrations, the project may elect to leave the rods in place for long-term vapor sampling or may install permanent vapor sampling stations (using sintered metallic filters). Direct-push technology rods that are left in place will be completed at the upper 45.7 cm (18 in.) with concrete pads and brass survey markers (consistent with groundwater well installations).

Figure 7-2. Shallow Soil Vapor Sampling Around the Plutonium Finishing Plant.



E0110060

Step 7 – Optimize the Design

Figure 7-3. Typical Storage Module in Low-Level Burial Ground Retrievable Storage Units Showing Vent Riser (from Last et al. 1989).

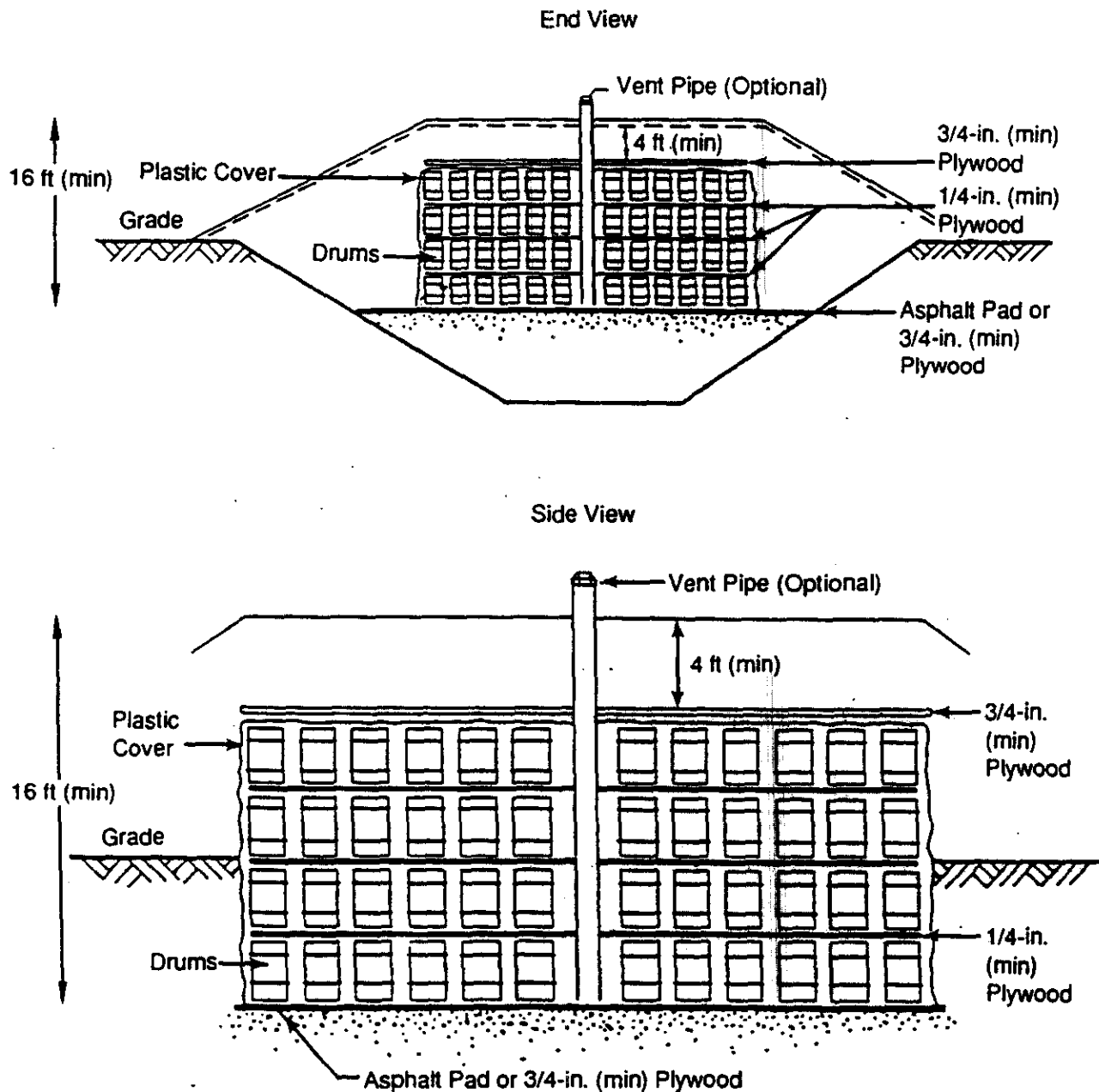


Figure 7-4. Location of Drum Storage Area and French Drains Within the PFP Protected Area.

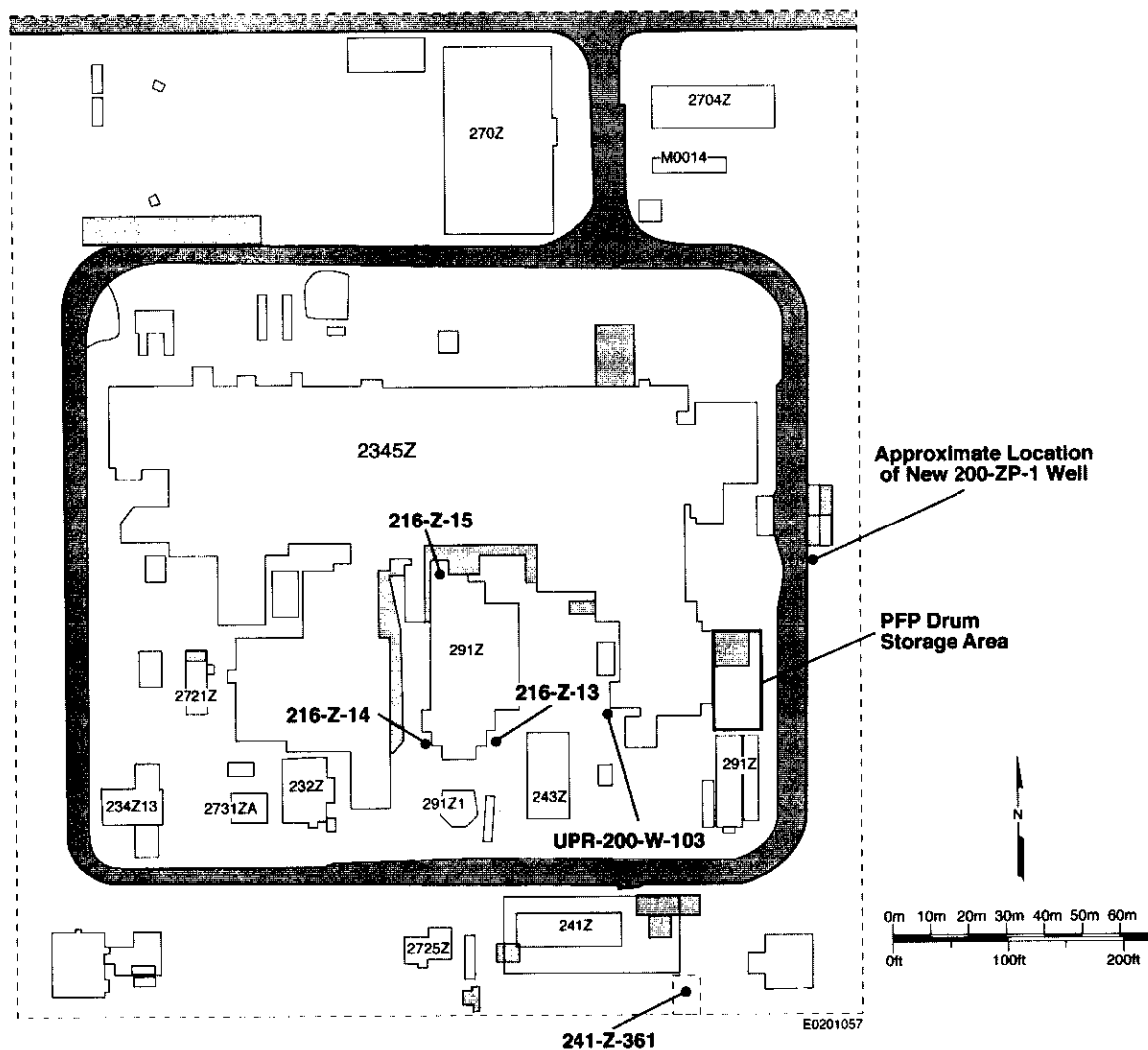
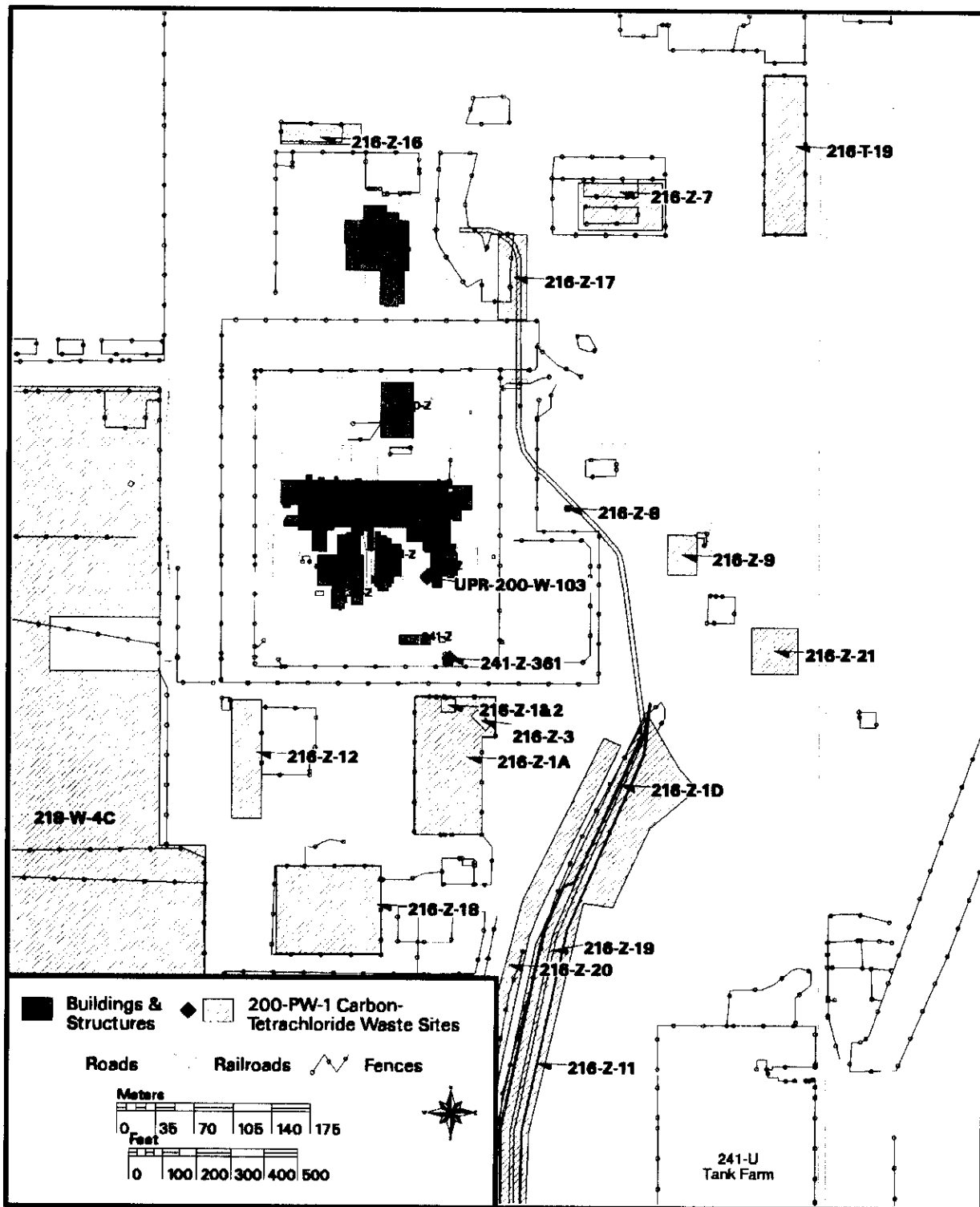


Figure 7-5. Location of Liquid Waste Discharge Sites.



BHI:mas 11/20/00 /home/masye/aml/pw1_sites_b.aml Plotted 30-JAN-2002 Rev 2

Figure 7-6. Location of Liquid Discharge Pipelines.

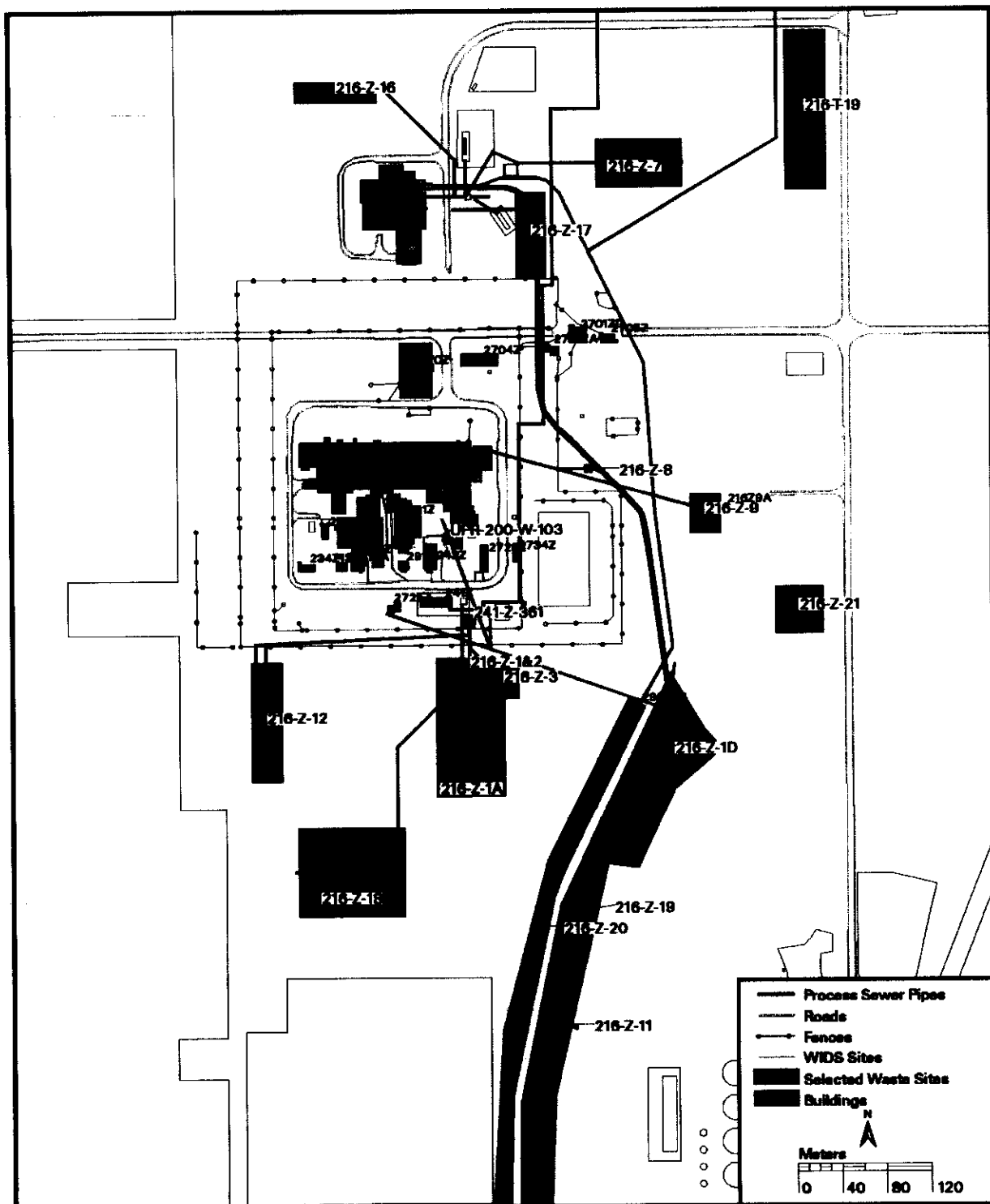


Table 7-7. Site Size and Number of Direct-Push Technology Locations in Liquid Waste Discharge Sites.

Release Modes	Known/Suspect Release Sites	Operable Unit	Site Area (m ²)	Relative Size ^a	Number of Direct-Push Technology Locations
Drum leaks	PFP drum storage area	N/A	250	M	2
PFP HVAC condensate and cooling water discharges	216-Z-13 french drain	200-MW-1	7	S	1
	216-Z-14 french drain	200-MW-1	7	S	1
	216-Z-15 french drain	200-MW-1	7	S	1
	216-Z-21 Pond	200-MW-1	1,764	L	3
	216-Z ditches site (216-Z-1D, 216-Z-11, 216-Z-19, 216-Z-20)	200-CW-5	N/A	L	3
Liquid waste discharges	216-T-19 Crib	200-PW-1	3,094	L	3
	216-Z-1A (including 216-Z-1, 216-Z-2, 216-Z-3)	200-PW-1	2,940	L	3
	216-Z-7 Crib	200-LW-2	864	M	2
	216-Z-8 french drain	200-PW-6	7	S	1
	216-Z-9 Trench	200-PW-1	167	M	2
	216-Z-12 Crib	200-PW-1	549	M	2
	216-Z-16 Crib	200-LW-2	165	M	2
	216-Z-17 Trench	200-LW-2	488	M	2
	216-Z-18 Crib	200-PW-1	189	M	2

^a The size break points for this table are as follows:

- Small site (S): 0 – 100 m²
- Medium site (M): 100 – 1,000 m²
- Large site (L): >1,000 m²

N/A = not applicable

An advanced drive-point technology, the wire-line cone penetrometer, may be considered for characterization of carbon tetrachloride in the upper 35 m (114.8 ft) of the vadose zone. The wire-line cone penetrometer avoids a potential difficulty inherent in direct push sampling: removing the rods and reinserting them in the same hole. Several advanced characterization tools can be used with the wire-line cone penetrometer to sample carbon tetrachloride in the vadose zone. Among those tools, the wire-line cone penetrometer gas sampler may be used to draw soil gas samples to the surface for analysis and the wire-line cone penetrometer grouting module may be used to grout the hole after sampling has been completed. The ribbon non-aqueous phase liquid sampler may be used to determine if non-aqueous phase carbon tetrachloride is present in areas of high vapor concentrations.

Step 7 – Optimize the Design

Use of these characterization tools will depend on their availability and cost-effectiveness. The key features and bases for each component of the Step I sampling design are presented in Table 7-6. The area of each liquid waste discharge site was used to determine the number of direct-push technology locations in that site, as shown in Table 7-7.

7.4.2 Potential Sample Design Limitations

It is noted that the sampling design may not fill all vadose zone data gaps. As presented, the sampling design allows for reassessment of characterization, remediation, and financial priorities. This approach recognizes that decision makers will be better positioned to initiate expensive deep vadose zone characterization after conceptual model data gaps have been filled.

Other potential limitations of the proposed sampling designs are identified below:

- Contamination levels in certain areas may be significant and would require employment of substantial contamination controls to ensure the health and safety of workers and protection of the environment and equipment.
- Analysis of VOA contaminants imposes sample hold-time limitations. To overcome these limits, prior planning and coordination will be required to avoid violating the holding times.
- Access to the burial grounds may be limited because of worker protection requirements, radiological constraints, or other constraints.
- Access to pipelines or other potential release sites within the PFP exclusion zone (i.e., the area between the two fences) may be limited by Hanford Site security constraints.
- Shallow soil gas sampling imposes the need to collect samples during soil venting periods to avoid erroneous nondetection results.
- Vapor sampling results must be carefully evaluated against pre-established logic to avoid erroneous conclusions.

8.0 OBSERVATIONS AND RECOMMENDATIONS

8.1 REMEDIAL ACTION CONSIDERATIONS

The sampling design developed in this DQO process does not formulate remedial action decisions. However, some of the information obtained during the DQO process will support remedial decision making. The following action is recommended for consideration by the project team:

- Isolate uncontrolled water influx within the geographic area of this study. Because the infiltration of discharged waters through the vadose zone could create contaminant migration pathways to groundwater, it is recommended that all uncontrolled water releases be identified and shut off within the study area.

8.2 PERIODIC REVIEW OF DATA QUALITY OBJECTIVES

This project is complex, relying on vapor and soil monitoring/sampling in a multi-stage program. It is likely that the dynamics associated with remedial decisions, vapor extraction, and pump-and-treat operations will change the subsurface conditions. Therefore, it is recommended that this DQO process be periodically reviewed for relevance.

9.0 REFERENCES

- ARH, 1976, *Z Plant Liquid Waste Disposal Through the 241-Z Vault*, ARH-CD-323, Atlantic Richfield Hanford Company, Richland, Washington.
- Bauer, R. G., 2002, *Remedial Investigation Data Quality Objectives Summary Report for the 200-PW-1 Operable Unit Representative Waste Sites*, BHI-01477, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.
- BHI, 1995a, *200-ZP-1 Groundwater Sampling and Analysis Plan/Quality Assurance Plan*, BHI-00038, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.
- BHI, 1995b, *DNAPL Investigation Report*, BHI-00431, Rev. 00, Bechtel Hanford, Inc., Richland, Washington.
- BHI, 1998, *Hanford Site Atlas*, BHI-01119, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.
- BHI, 2001, *Well Deepening and Supplemental Vadose Zone Characterization at the Hanford 200 West Area 216-Z-9 Trench*, BHI-01462, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- BHI-EE-01, *Environmental Investigations Procedures*, Bechtel Hanford, Inc., Richland, Washington.
- Borghese, J. W., R. E. Peterson, L. C. Swanson, and P. B. Tolley, 1998, *Fiscal Year 1997 Annual Report for the 100-NR-2, 200-UP-1, and 200-ZP-1 Operations and Operable Units*, BHI-01126, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- Chiaromonte, G. R., C. W. Denslow, A. J. Knepp, R. D. Landau, and S. Panday, 1996, *Hanford Sitewide Groundwater Remediation Strategy – Groundwater Contaminant Predictions*, BHI-00469, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- Conca, J. L., and J. V. Wright, 1992, "Diffusion and Flow in Gravel, Soil, and Whole Rock," *Applied Hydrogeology*, Vol. 1, pp. 5-24.
- Curren, E. F., 1972, *200 Areas Disposal Sites for Radioactive Liquid Wastes*, ARH-947, Atlantic Richfield Hanford Company, Richland, Washington.
- DOE, 1999a, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, DOE/EIS-0222-F, U.S. Department of Energy, Washington, D.C.
- DOE, 1999b, *Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, 6450-01-P, U.S. Department of Energy, Washington, D.C.

- DOE-RL, 1991, *Expedited Response Action Proposal (EE/CA & EA) for 200 West Area Carbon Tetrachloride Plume*, DOE/RL-91-32, Draft B, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1992, *Z Plant Source Aggregate Area Management Study Report*, DOE/RL-91-58, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1996, *200-ZP-1 IRM Phase II and III Remedial Design Report*, DOE/RL-96-07, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL 1997a, *Hanford Sitewide Groundwater Remediation Strategy*, DOE/RL-94-95, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1997b, *Waste Site Grouping for 200 Areas Soil Investigations*, DOE/RL-96-81, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1998, *Hanford Analytical Services Quality Assurance Requirements Documents, Volume 4: Laboratory Technical Requirements*, DOE/RL 96-68, Rev. 2, Vol. 4, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 1999, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*, DOE/RL-98-28, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 2000, *Fiscal Year 1999 Annual Summary Report for the 200-UP-1, 200-ZP-1, and 100-NR-2 Pump-and-Treat Operations and Operable Units*, DOE/RL-99-79, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 2001, *Fiscal Year 2000 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations*, DOE/RL-2000-71, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-RL, 2002, *200-PW-1 Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan*, DOE/RL-2001-01, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- Ecology, EPA, and DOE, 1998, *Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.
- Ellerd, M. G., J. W. Massmann, D. P. Schwaegler, and V. J. Rohay, 1999, "Enhancements for Passive Vapor Extraction: The Hanford Study, Ground Water," Vol. 37, No. 3, May-June 1999, pp. 427-437.

References

- EPA, 1997, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*, SW-846, Update III, U.S. Environmental Protection Agency, Washington, D.C.
- EPA, 2001, *USDOE Hanford Site First Five Year Review Report*, U.S. Environmental Protection Agency, Region 10, Hanford Project Office, Seattle, Washington.
- EPA, Ecology, and DOE, 1995, *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.
- EPA and Ecology, 1992, *Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume*, letter from R. F. Smith, U.S. Environmental Protection Agency, Region 10, and R. Stanley, Washington State Department of Ecology, to R. D. Izatt, U.S. Department of Energy, Richland Operations Office, CCN 9200423, dated January 21, 1992, U.S. Environmental Protection Agency, Region 10, and Washington State Department of Ecology, Lacey, Washington.
- Faurote, J. M., 2002, *Borehole Summary Report for Well 299-W15-42 (C3803) and Borehole 299-W15-764 (C3494), 200-ZP-1 Operable Unit*, BHI-01620, Rev. 0, Bechtel Hanford Inc., Richland, Washington.
- Gerber, M. S., 1997, *History and Stabilization of the Plutonium Finishing Plant (PFP) Complex, Hanford Site*, HNF-EP-0924, Fluor Daniel Hanford, Inc., Richland, Washington.
- Jensen, D. B., 1990, *Plutonium Finishing Plant Wastewater Stream-Specific Report*, WHC-EP-0342, Addendum 8, Westinghouse Hanford Company, Richland, Washington.
- Kasper, R. B., 1982, *216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium*, RHO-ST-44, Rockwell Hanford Company, Richland, Washington.
- Last, G. V., B. N. Bjornstad, M. P. Bergeron, D. W. Wallace, D. R. Newcomer, J. A. Schramke, M. A. Chamness, C. S. Cline, S. P. Airhart, and J. S. Wilber, 1989, *Hydrogeology for the 200 Areas Low-Level Burial Grounds – An Interim Report*, PNL-6820, Pacific Northwest Laboratory, Richland, Washington.
- Last, G. V., and V. J. Rohay, 1993, *Refined Conceptual Model for the Volatile Organic Compounds – Arid Integrated Demonstration and 200 West Area Carbon Tetrachloride Expedited Response Action*, PNL-8597, Pacific Northwest Laboratory, Richland, Washington.
- Ludowise, J. D., 1978, *Report on Plutonium Mining Activities at 216-Z-9 Enclosed Trench*, RHO-ST-21, Rockwell Hanford Operations, Richland, Washington.

References

- Marratt, M. C., R. B. Kasper, and A. E. VanLuik, 1984, *The 216-Z-8 French Drain Characterization Study*, RHO-RE-EV-46P, Rockwell Hanford Operations, Richland, Washington.
- Maxfield, H. L., 1979, *200 Areas Waste Sites Handbook*, 3 vols., RHO-CD-673, Rockwell Hanford Operations, Richland, Washington.
- Piepho, M. G., 1996, *Numerical Analysis of Carbon Tetrachloride Movement in the Saturated and Unsaturated Zones in the 200 West Area, Hanford Site*, BHI-00459, Rev. 00, Bechtel Hanford, Inc., Richland, Washington.
- PNL, 1994, *Hydrostratigraphy and Recharge Distributions from Direct Measurements of Hydraulic Conductivity Using the UFA Method*, PNL-9424, Pacific Northwest Laboratory, Richland, Washington.
- PNNL, 1999, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*, PNNL-12086, Pacific Northwest National Laboratory, Richland, Washington.
- PNNL, 2000, *Subsurface Transport Over Multiple Phases (STOMP)*, PNNL-12034, Pacific Northwest National Laboratory, Richland, Washington.
- PNNL, 2001, *Hanford Site Groundwater Monitoring for Fiscal Year 2000*, PNNL-13404, Pacific Northwest National Laboratory, Richland, Washington.
- Price, S. M., M. K. Additon, and R. B. Kasper, 1979, *Distribution of Plutonium and Americium Beneath the 216-Z-1A Crib: A Status Report*, RHO-ST-17, Rockwell Hanford, Inc., Richland, Washington.
- Resource Conservation and Recovery Act of 1976*, 42 U.S.C. 6901, et seq.
- Riley, G. L., 1998, *Residual DNAPL Source Evaluation Using Concentration Rebound Data*, M.S. Thesis, University of Washington, Seattle, Washington.
- Rohay, V. J., 1994, *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford*, WHC-SD-EN-TI-248, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Rohay, V. J., 1995, *FY 1993 Wellfield Enhancement Status Report and Data Package for the 200 West Area Carbon Tetrachloride Expedited Response Action*, BHI-00105, Rev. 00, Bechtel Hanford, Inc., Richland, Washington.
- Rohay, V. J., 1997, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*, BHI-01105, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

References

- Rohay, V. J., 2000, *Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992 – September 1999*, BHI-00720, Rev. 4, Bechtel Hanford, Inc., Richland, Washington.
- Rohay, V. J., 2001, *Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992-September 2000*, BHI-00720, Rev. 5, Bechtel Hanford, Inc., Richland, Washington.
- Rohay, V. J., and W. J. McMahon, 1996, *Airflow Modeling Report for Vapor Extraction Operations at the 200-ZP-2 Operable Unit (Carbon Tetrachloride Expedited Response Action)*, BHI-00882, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- Smith, A. E., 1973, *Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench*, ARH-2915, Atlantic Richfield Hanford Company, Richland, Washington.
- Swanson, L. C., V. J. Rohay, and J. M. Faurote, 1999, *Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/Technetium Plumes in the 200 West Area: 1994 Through 1999 Update*, BHI-01311, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- Truex, M. J., R. J. Cameron, M. D. Johnson, and S. W. Peterson, 2001, *Technology Alternatives Baseline Report for the 618-10 and 618-11 Burial Grounds, 300-FF-2 Operable Unit*, BHI-01484, Rev. 1, Bechtel Hanford, Inc., Richland, Washington.
- WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code*, as amended.
- WHC, 1992, *FY92 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Plume*, WHC-SD-EN-TI-063, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1993a, *Final Report for the Remote CCTV Survey of Abandoned Process Effluent Drain Lines 840 and 840D in Support of the 200 West Area Carbon Tetrachloride ERA*, WHC-SD-NR-ER-103, Rev. 0, Westinghouse Hanford, Inc., Richland, Washington.
- WHC, 1993b, *FY93 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Site*, WHC-SD-EN-TI-202, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1994, *Geologic Setting of the Low-Level Burial Grounds*, WHC-SD-EN-TI-290, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

References

DISTRIBUTION

U.S. Department of Energy
Richland Operations Office

B. L. Foley	A6-38
A. C. Tortoso (5)	A6-38

ERC Team

K. A. Anselm, CHI	H9-02
R. G. Bauer, CHI (5)	H9-03
L. M. Dittmer, BHI	H0-19
B. H. Ford, BHI	H0-21
J. D. Ludowise, CHI	H9-03
M. L. Mandis, CHI	H9-01
V. J. Rohay, CHI	H0-19
K. M. Singleton, CHI	H9-02
C. D. Wittreich, CHI	H9-03

Document and Information Services (3)	H0-09
DOE-RL Public Reading Room	H2-53
Hanford Technical Library	P8-55

